

INVENTOR:
TITLE:

SERIAL NO.:
ATTORNEY:

FANG, ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
10/214,436
G. MICHAEL ROEBUCK
FILING DATE: AUGUST 7, 1998
DOCKET NO.: 414-15493-CIP
TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

1/41

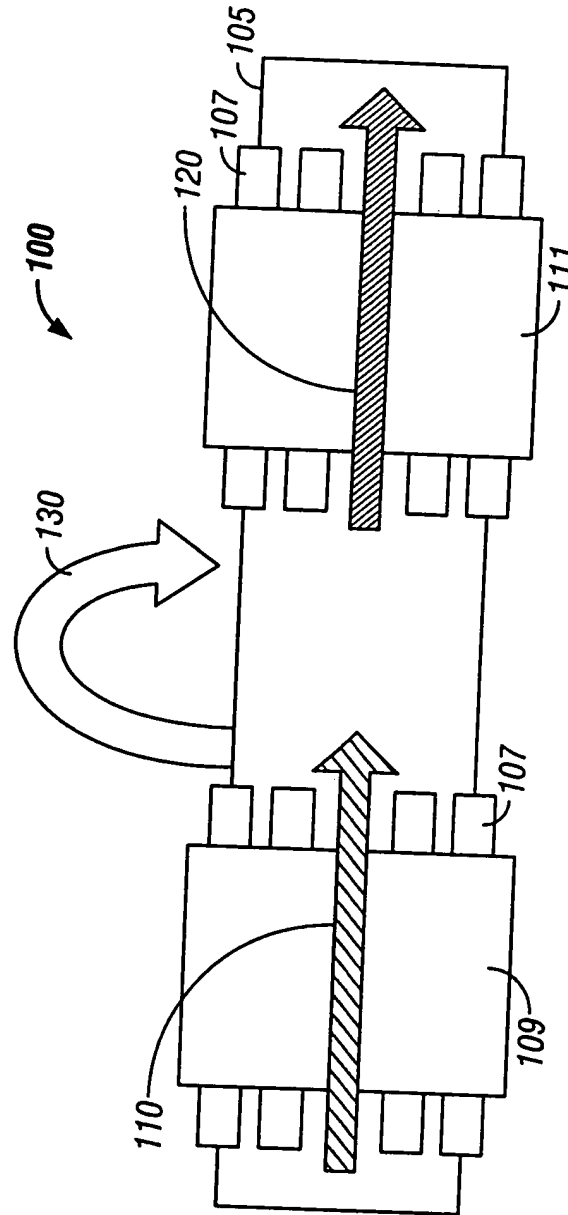


FIG. 1

INVENTOR:
TITLE:

FANINI, ET AL.

FILING DATE: AUGUST 7, 2002

METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS

SERIAL NO.:
ATTORNEY:

10/214,436

G. MICHAEL ROEBUCK

DOCKET NO.: 414-15493-CIP

TELEPHONE NO.: 713-266-1130

REPLACEMENT DRAWINGS

2/41

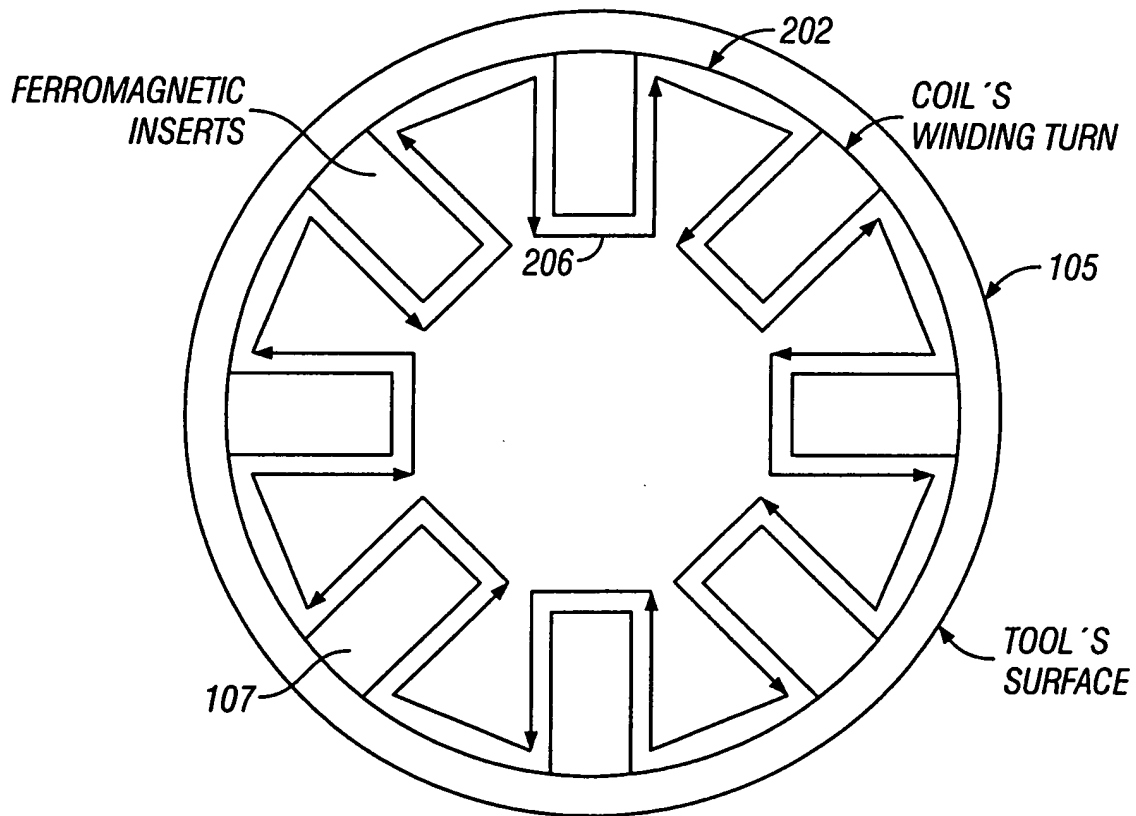


FIG. 2

INVENTOR:
TITLE:

FANINI ET AL.

FILING DATE: AUGUST 7, 2002

AND APPARATUS FOR A MULTI-COMPONENT INFORMATION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS

SERIAL NO.:
ATTORNEY:

10/214,436

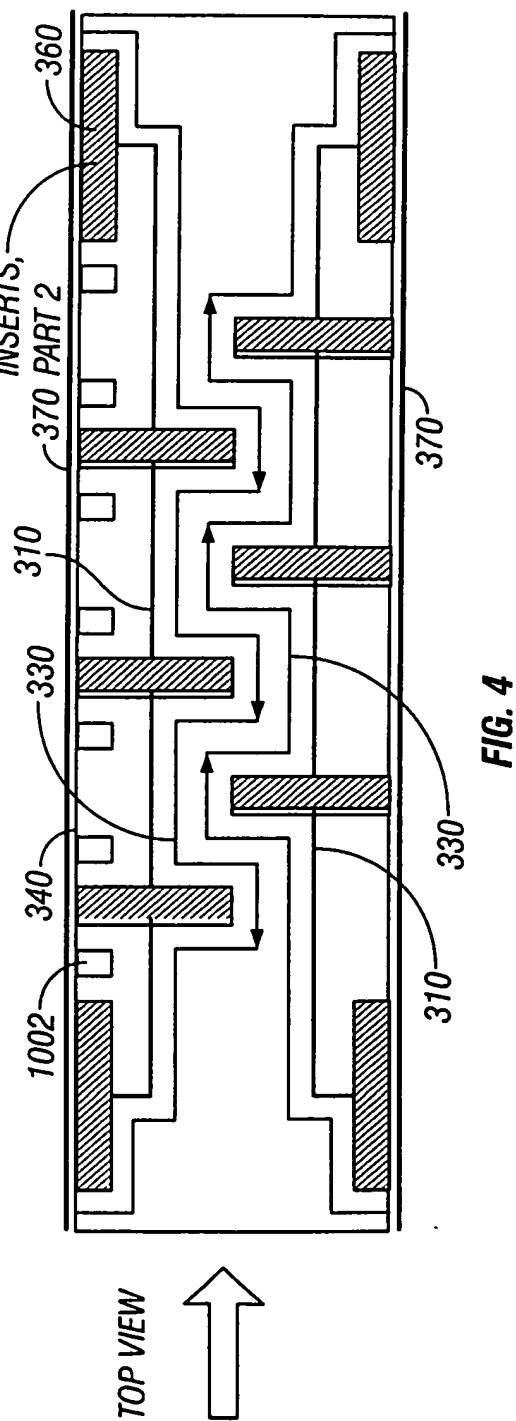
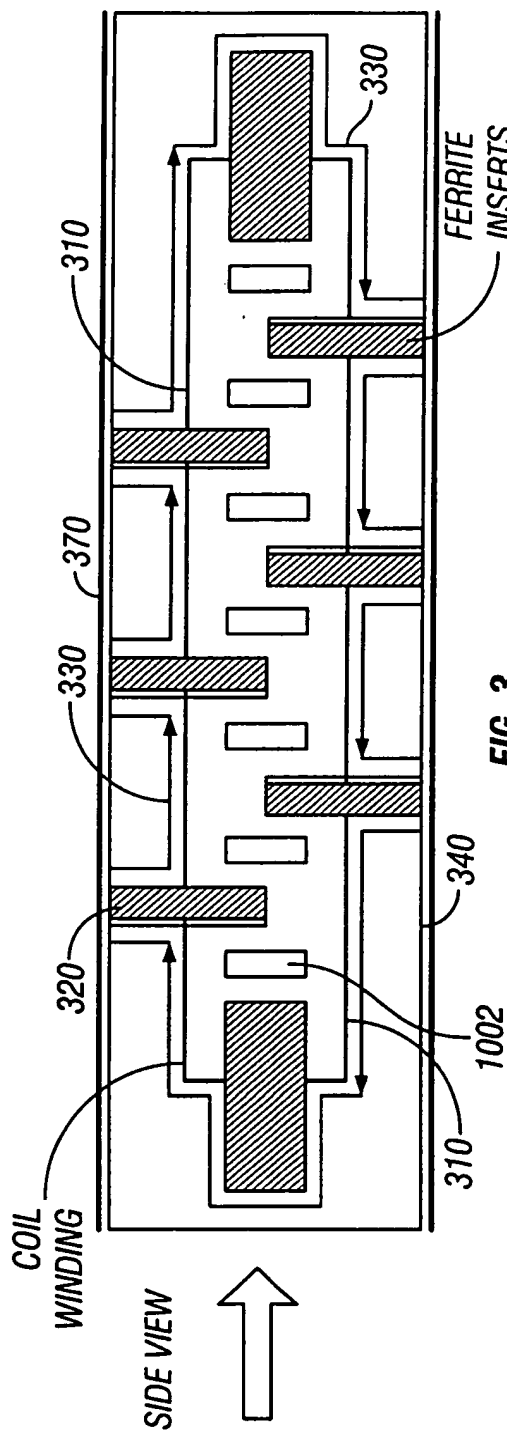
DOCKET NO.: 414-15493-CIP

G. MICHAEL ROEBUCK

TELEPHONE NO.: 713-266-1130

REPLACEMENT DRAWINGS

3/41



INVENTOR:
TITLE:

FANINI ET AL.

FILING DATE: AUGUST 7, 2002

METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS

SERIAL NO.:
ATTORNEY:

10/214,436

DOCKET NO.: 414-15493-CIP

G. MICHAEL ROEBUCK

TELEPHONE NO.: 713-266-1130

REPLACEMENT DRAWINGS

4/41

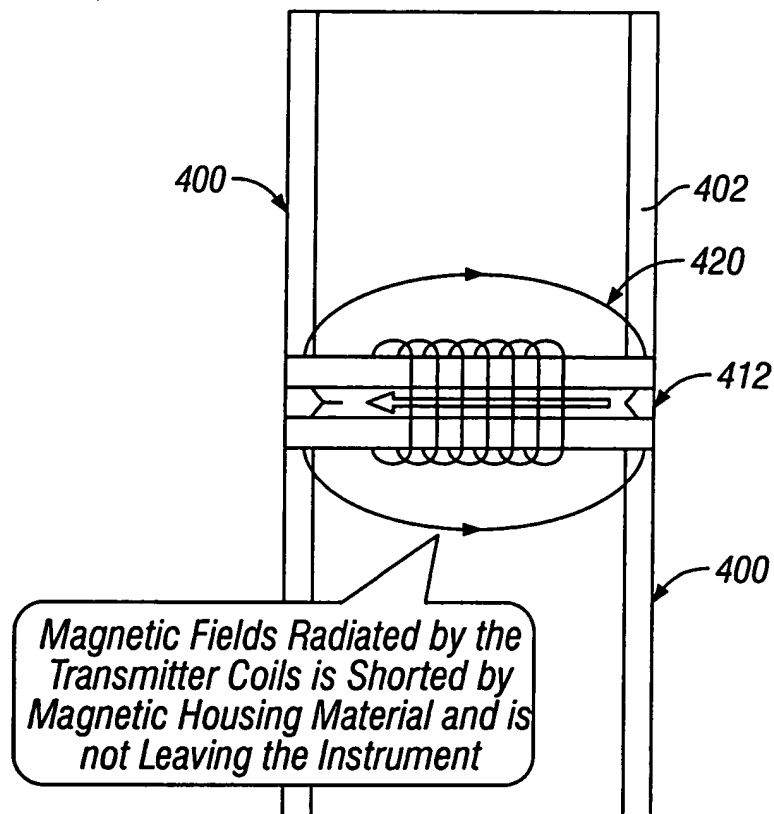


FIG. 5

INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT IN-STRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
DOCKET NO.: 414-15493-CIP
G. MICHAEL ROEBUCK TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

5/41

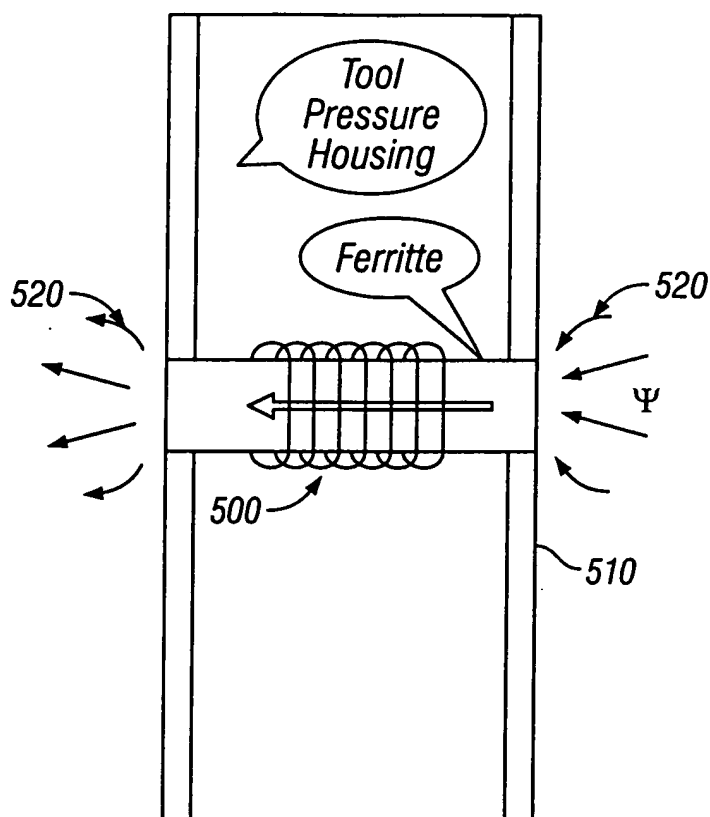


FIG. 6

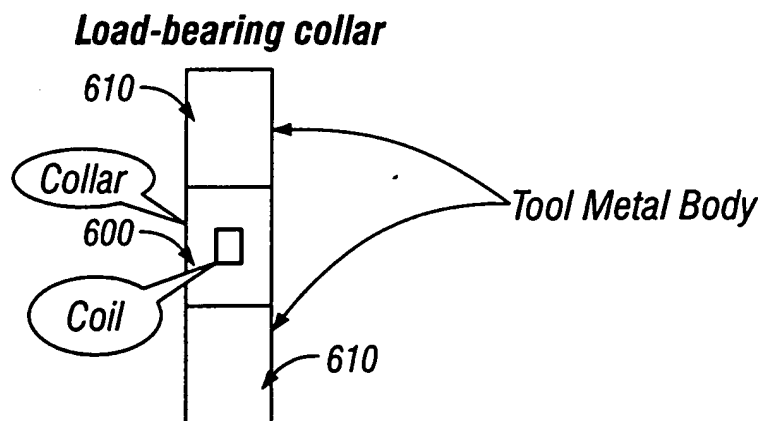


FIG. 7

6/41

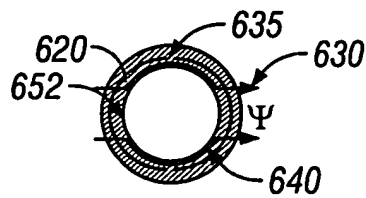
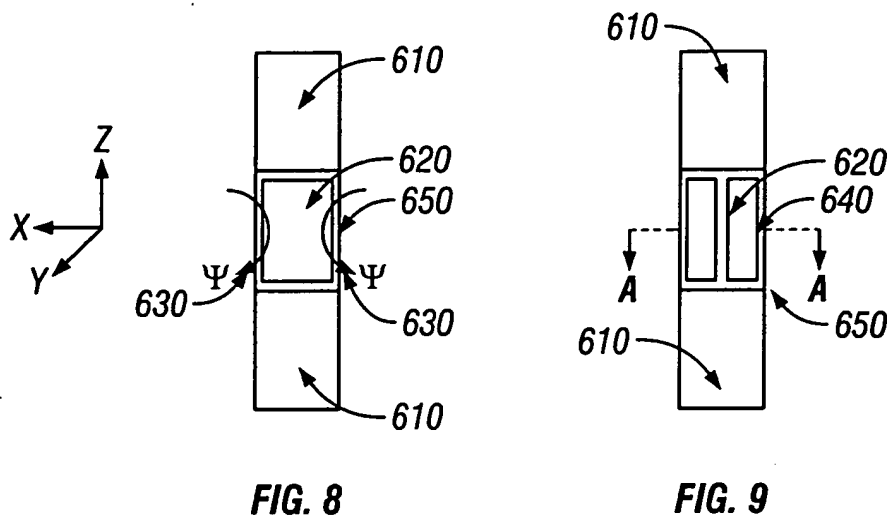
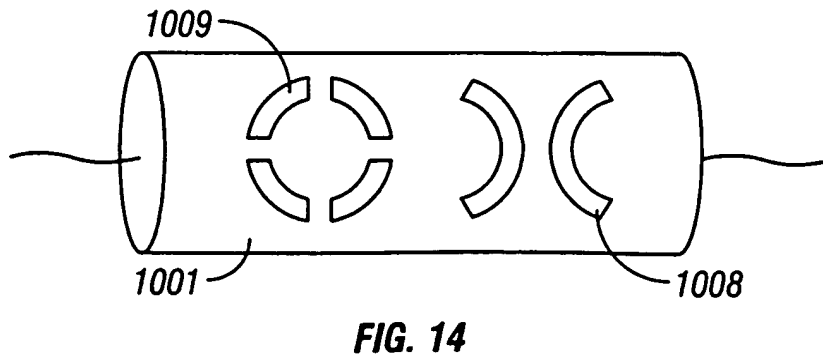
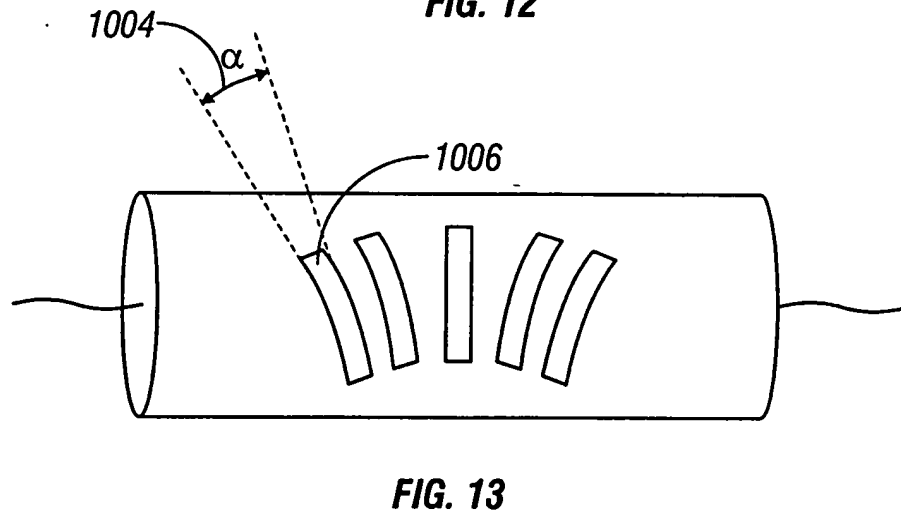
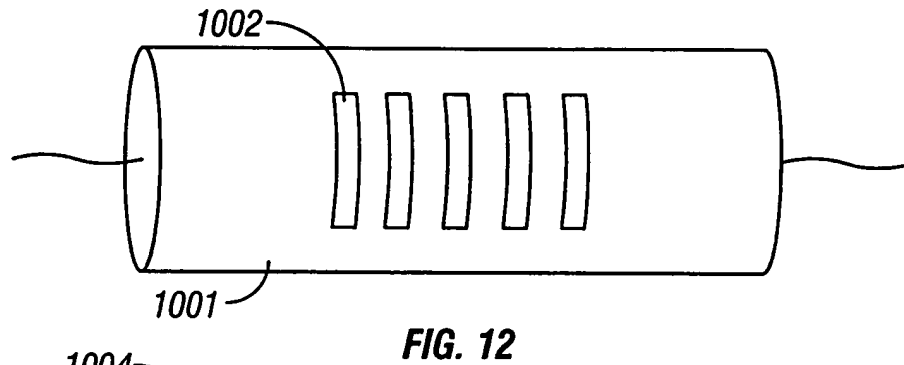
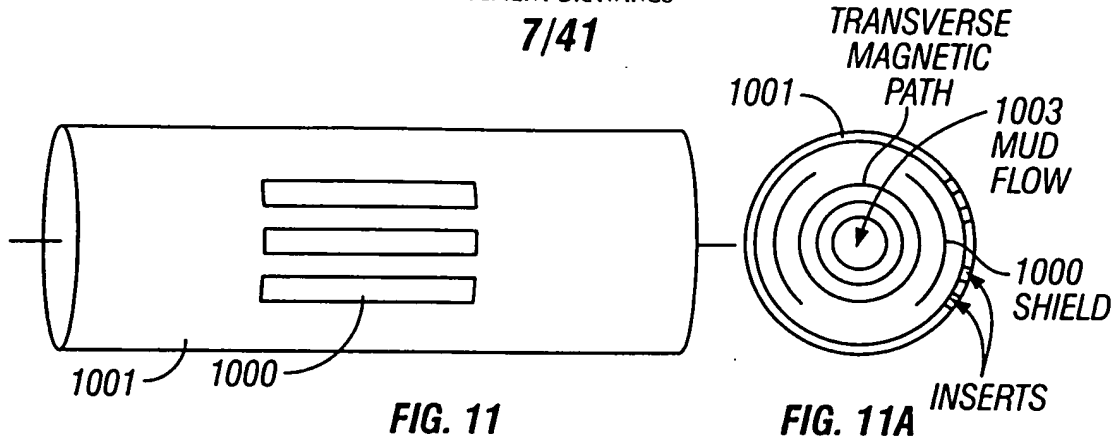


FIG. 10

7/41



INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
SERIAL NO.: 10/214,436
ATTORNEY: G. MICHAEL ROEBUCK
FILING DATE: AUGUST 7, 2002
DOCKET NO.: 414-15493-CIP
TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

8/41

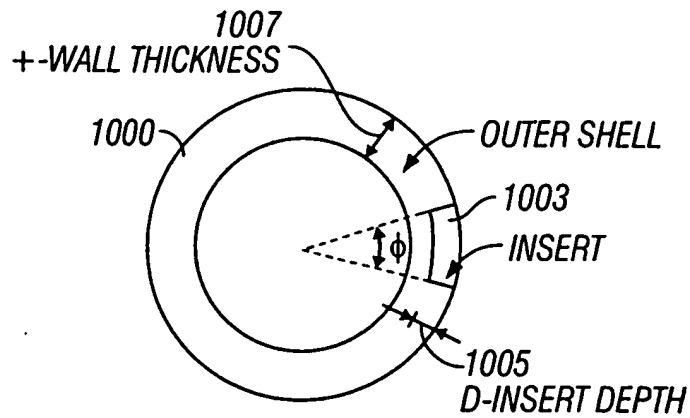


FIG. 15

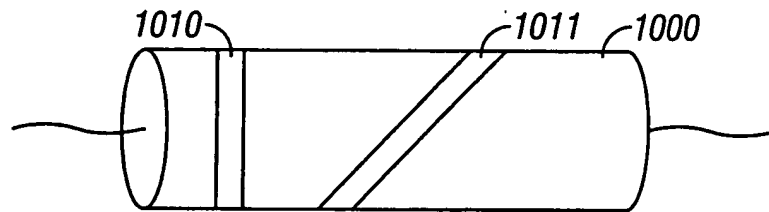


FIG. 16

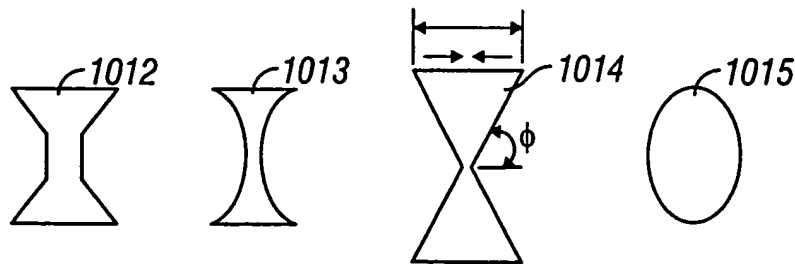


FIG. 17

FIG. 17A

FIG. 18

9/41

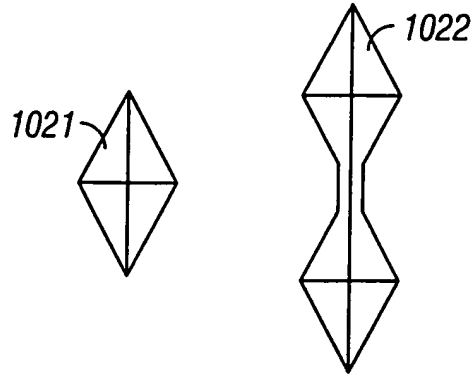


FIG. 19

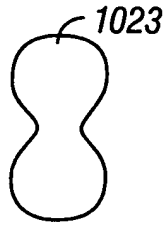


FIG. 20

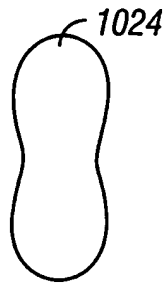


FIG. 20A

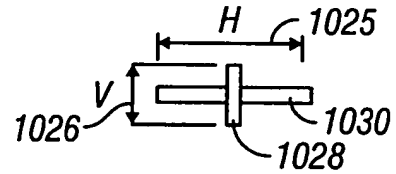


FIG. 21

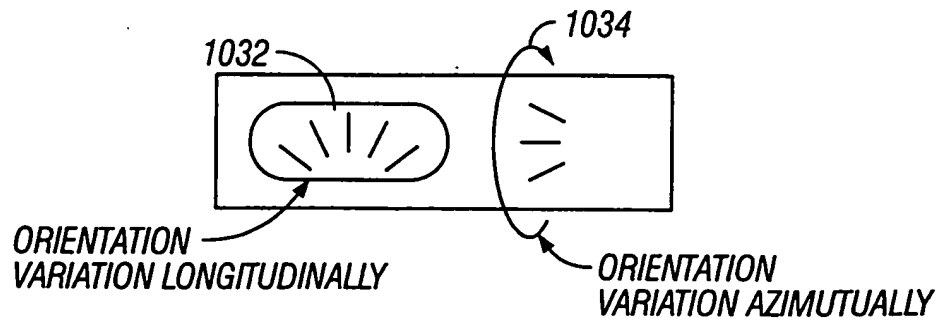


FIG. 22

10/41

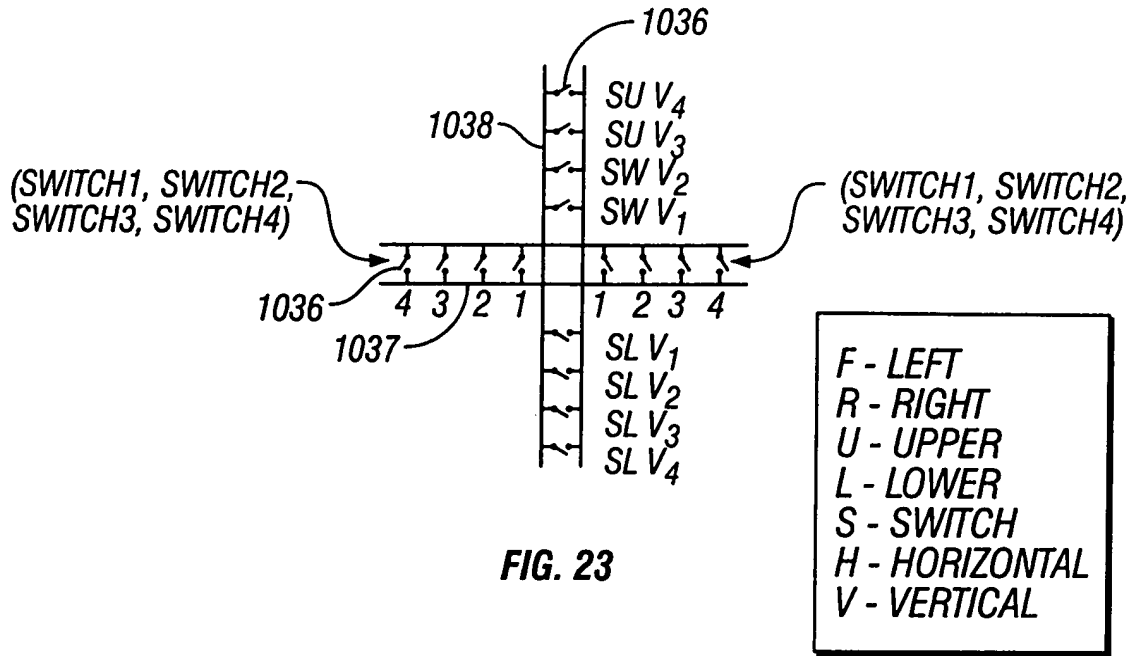


FIG. 23

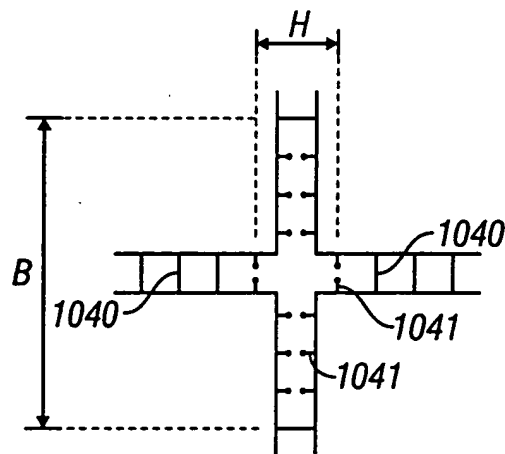


FIG. 24

INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
10/214,436
DOCKET NO.: 414-15493-CIP
G. MICHAEL ROEBUCK
TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

11/41

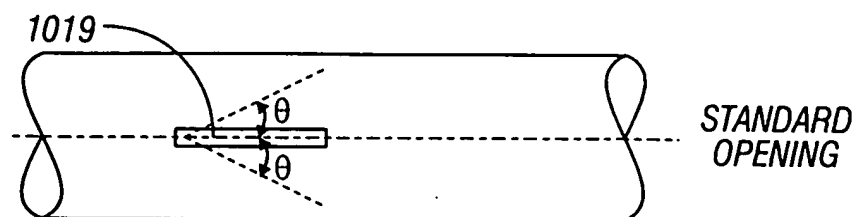


FIG. 25

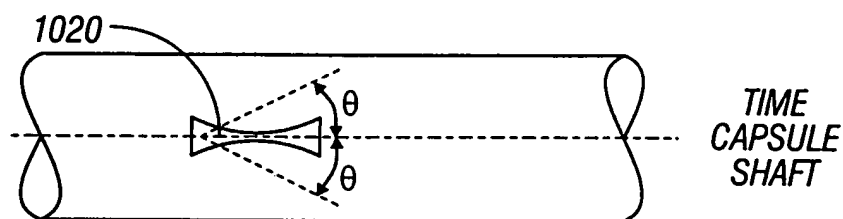


FIG. 26

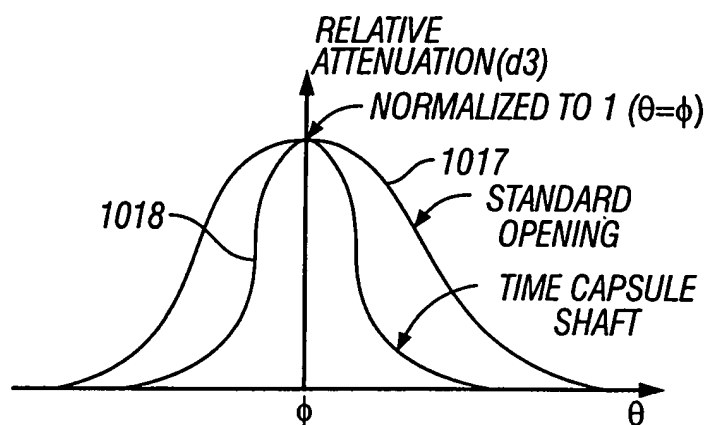


FIG. 27

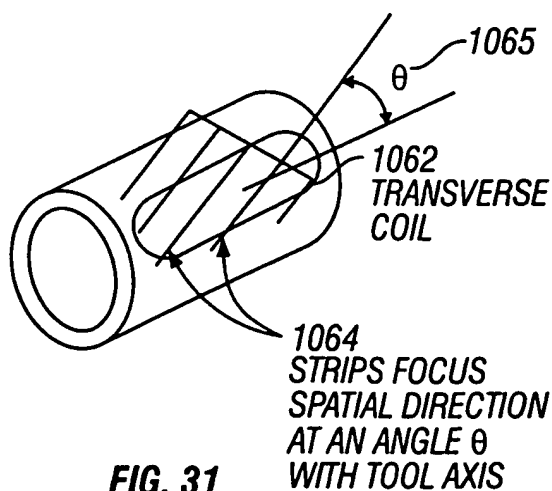


FIG. 31

INVENTOR:
TITLE:

FANINI ET AL.

FILING DATE:

AUGUST 7, 2002

METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS

SERIAL NO.:

10/214,436

DOCKET NO.:

414-15493-CIP

ATTORNEY:

G. MICHAEL ROEBUCK

TELEPHONE NO.:

713-266-1130

REPLACEMENT DRAWINGS

12/41

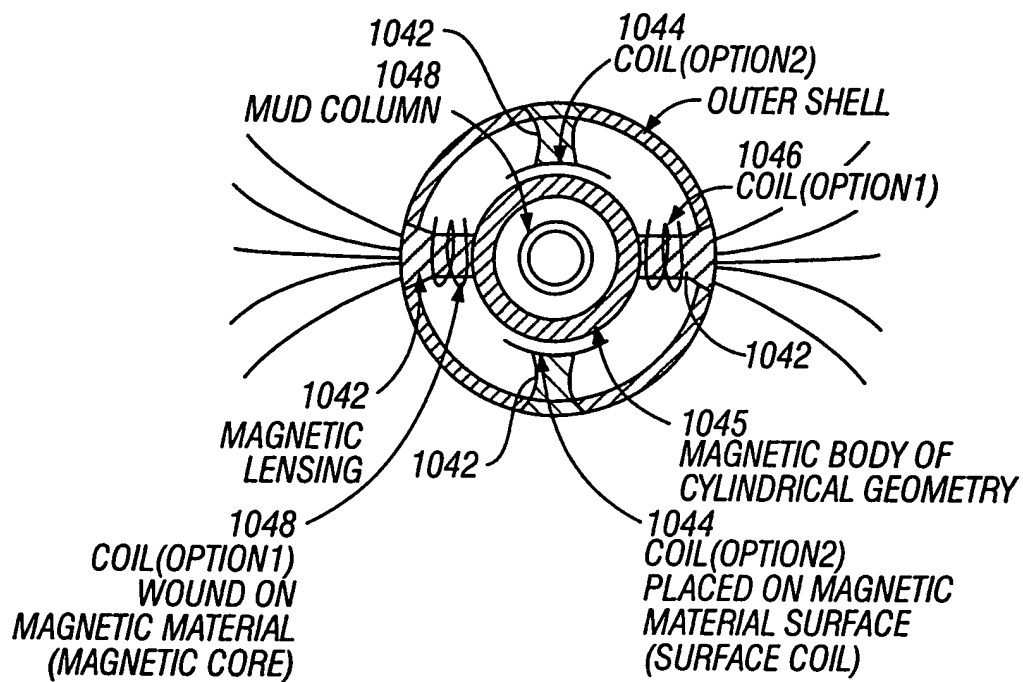


FIG. 28

13/41

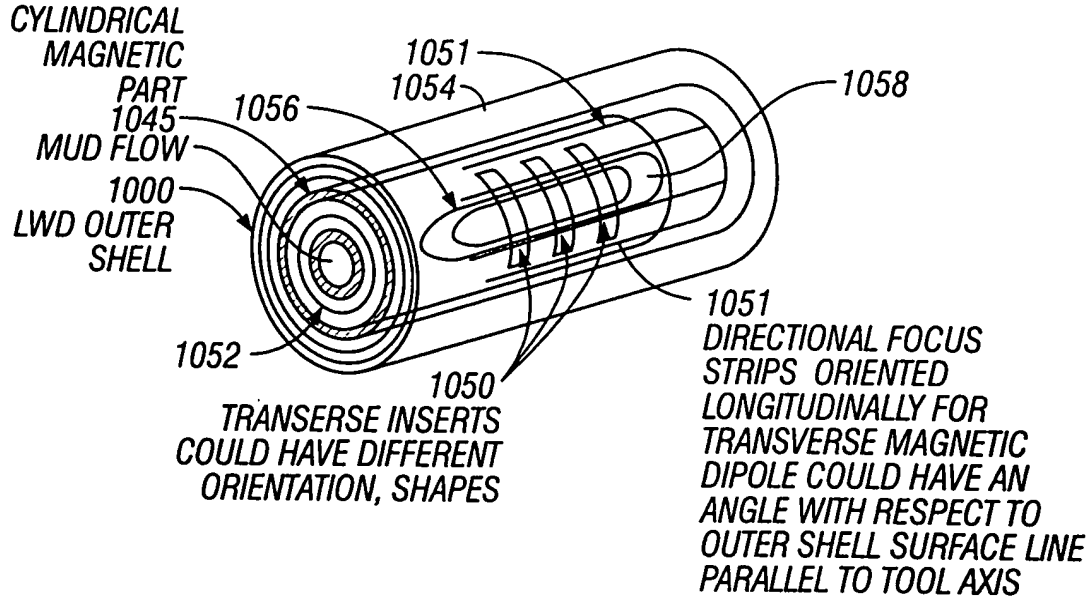


FIG. 29

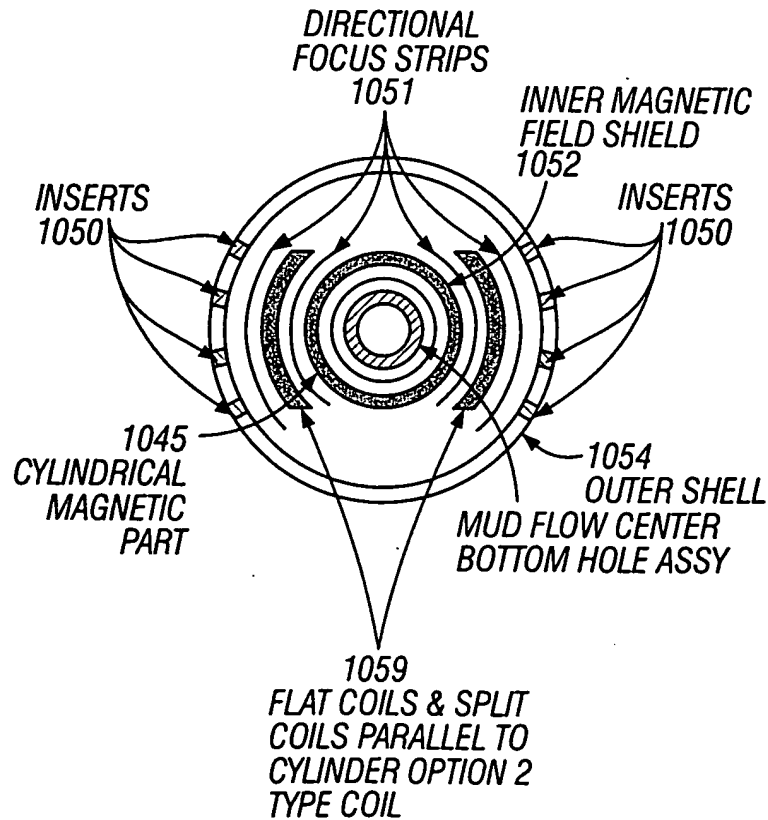


FIG. 30

14/41

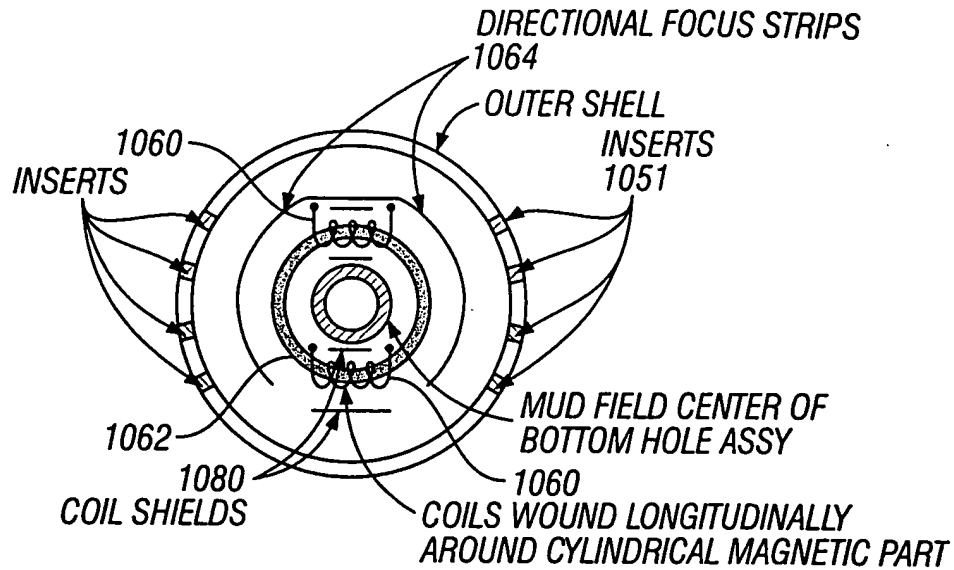


FIG. 32

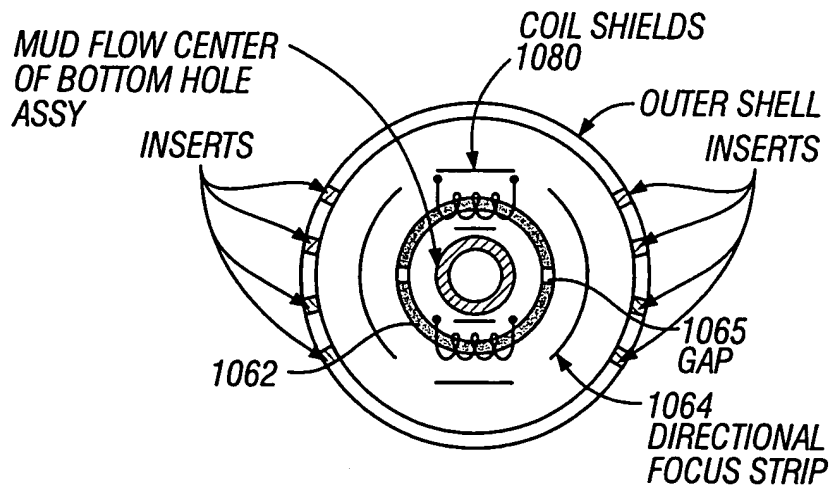


FIG. 33

INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INTERSECTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
10/214,436
G. MICHAEL ROEBUCK
FILING DATE: AUGUST 7, 2002
DOCKET NO.: 414-15493-CIP
TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

15/41

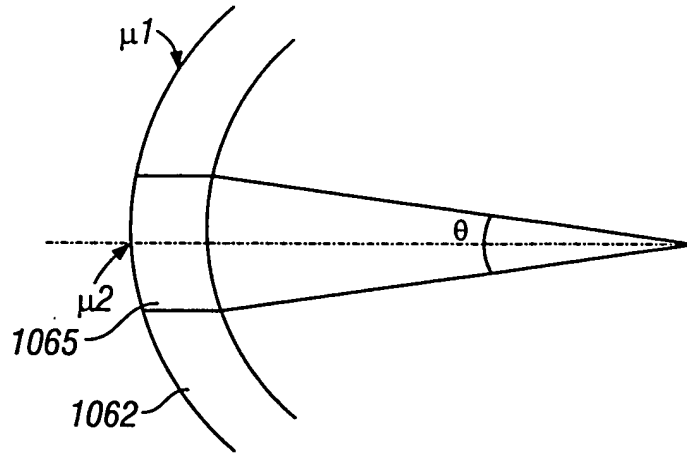


FIG. 34

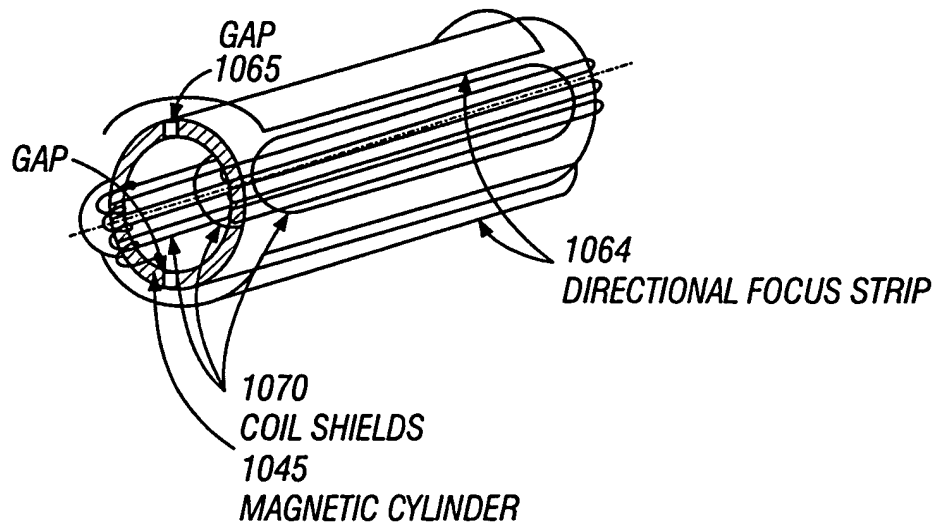


FIG. 35

16/41

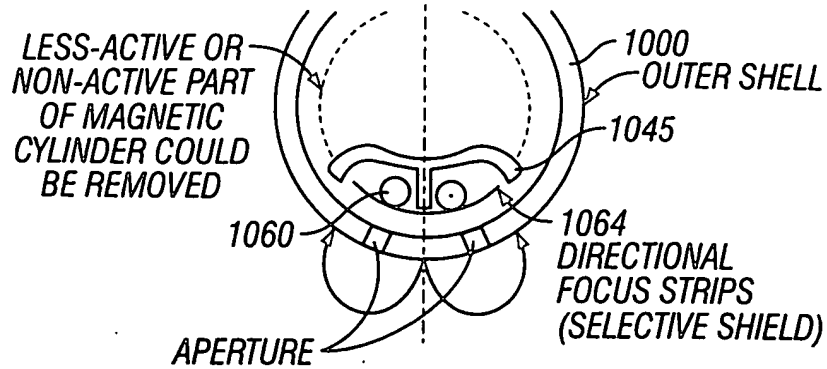


FIG. 36

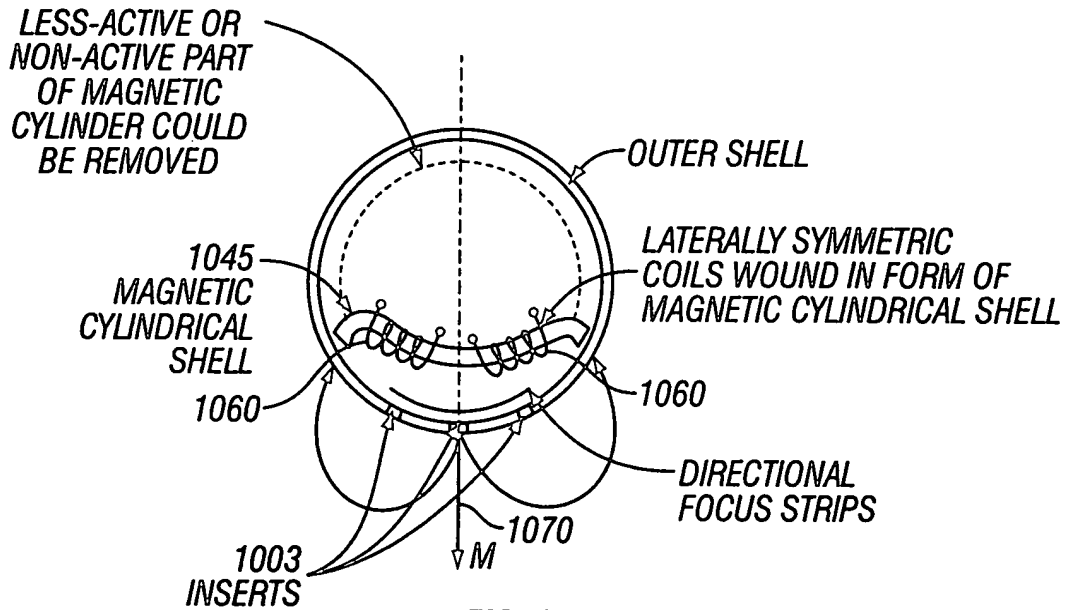


FIG. 37

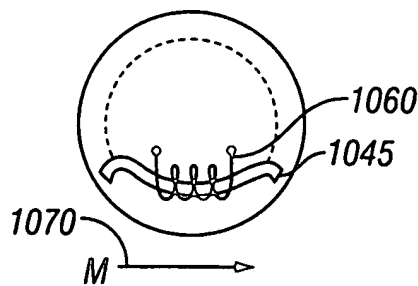


FIG. 38

17/41

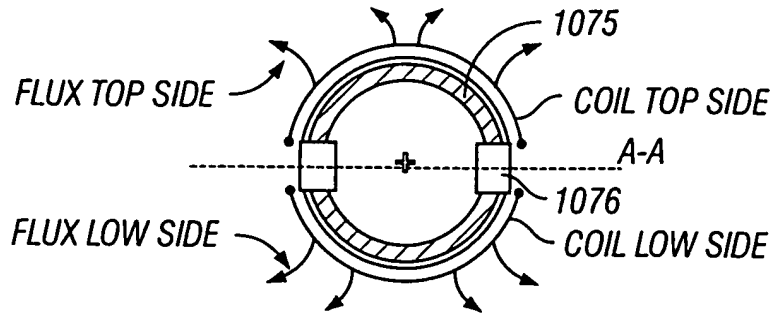


FIG. 39

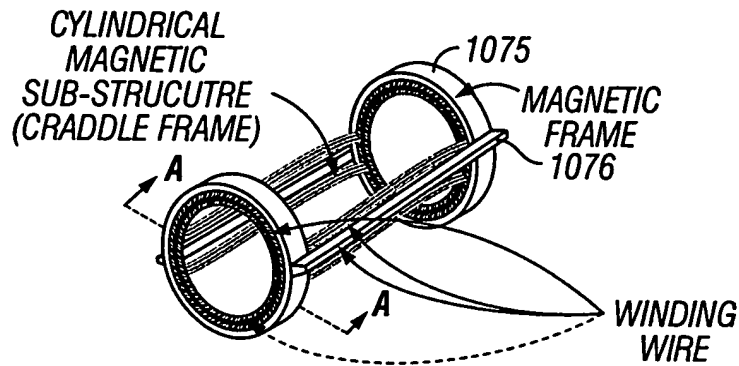


FIG. 40

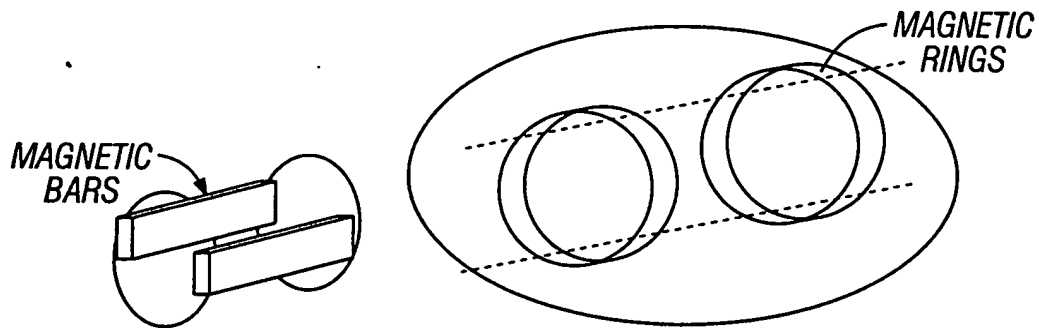


FIG. 41A

FIG. 41B

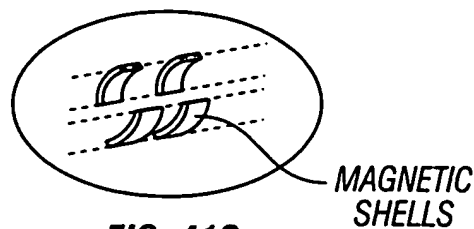


FIG. 41C

18/41

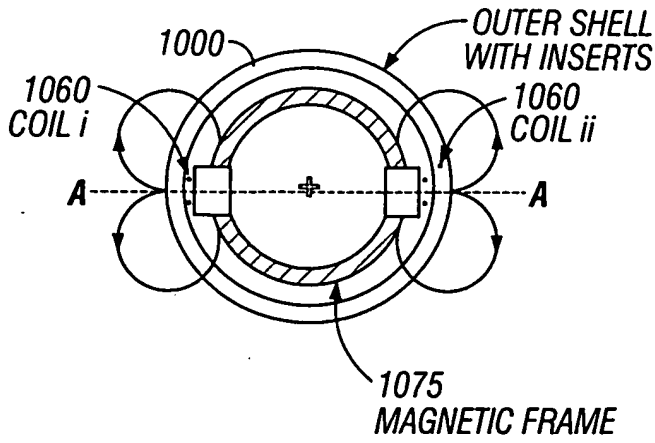


FIG. 42

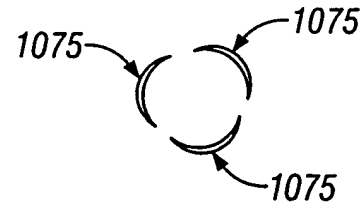


FIG. 43

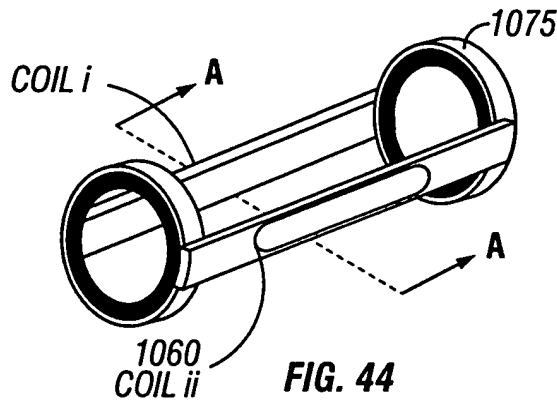


FIG. 44

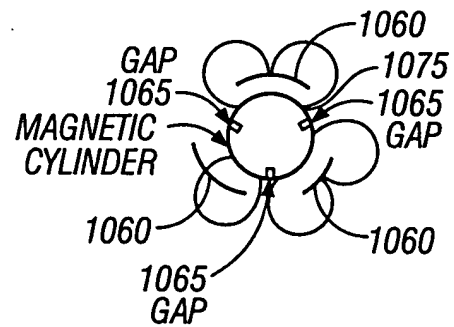


FIG. 45

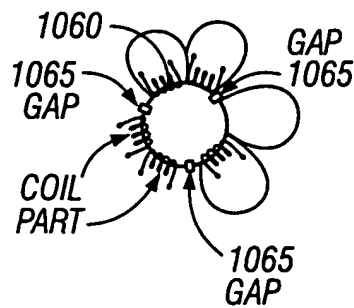


FIG. 46

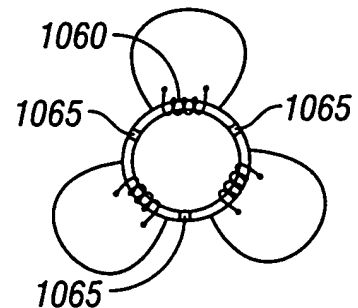


FIG. 47

19/41

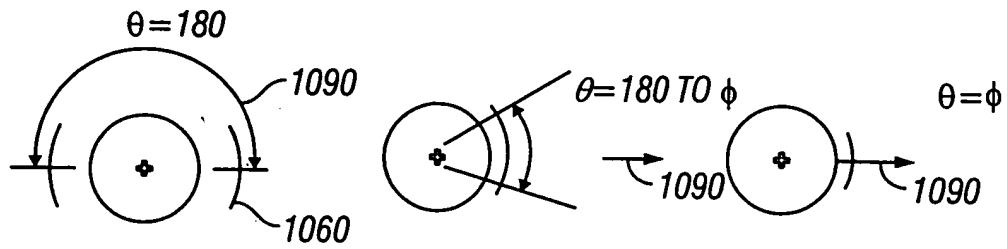


FIG. 48

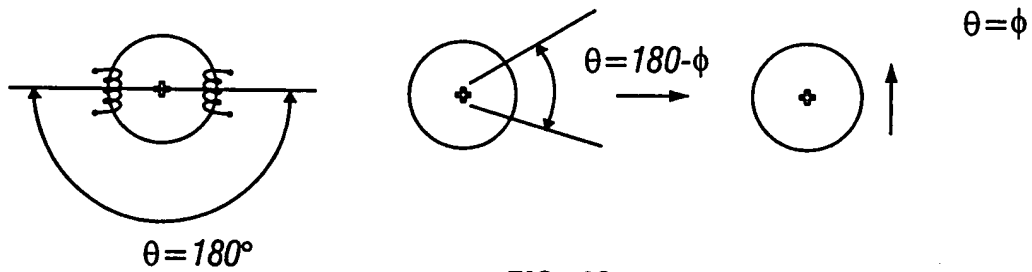


FIG. 49

INVENTOR:
TITLE:

FANINI ET AL.

FILING DATE: AUGUST 7, 2002

METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS

SERIAL NO.:
ATTORNEY:

10/214,436

DOCKET NO.: 414-15493-CIP

G. MICHAEL ROEBUCK

TELEPHONE NO.: 713-266-1130

REPLACEMENT DRAWINGS

20/41

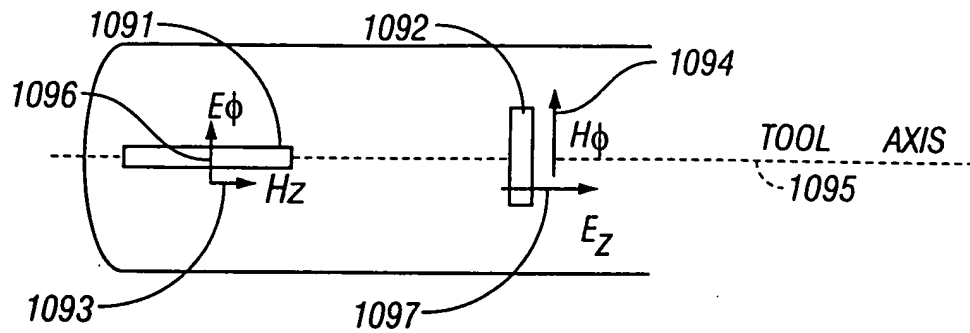


FIG. 50

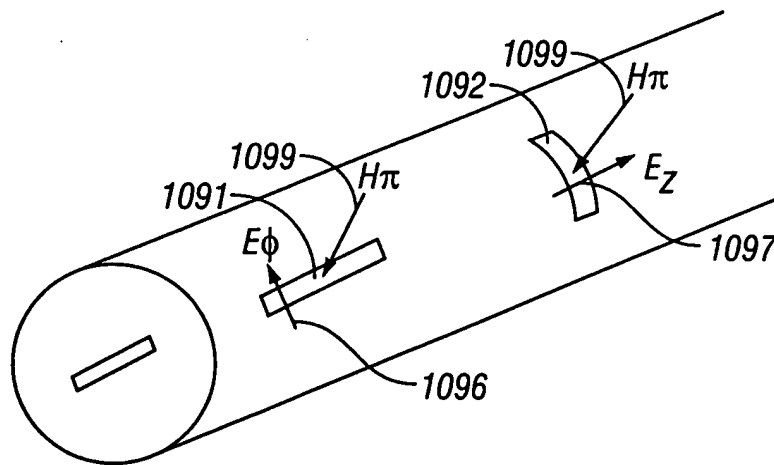


FIG. 51

INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
SERIAL NO.: 10/214,436
ATTORNEY: G. MICHAEL ROEBUCK

FILING DATE: AUGUST 7, 2002
DOCKET NO.: 414-15493-CIP
TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

21/41

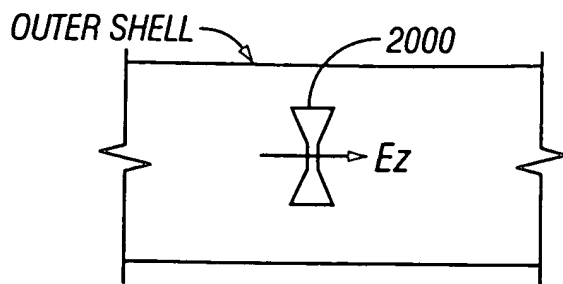


FIG. 52

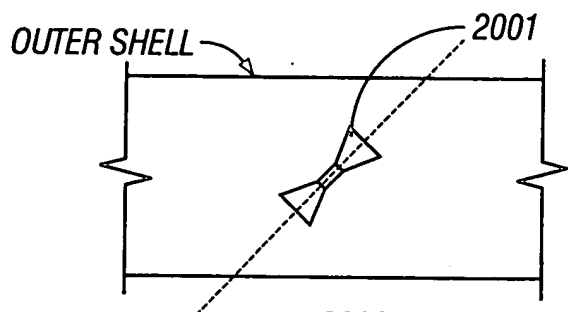


FIG. 53

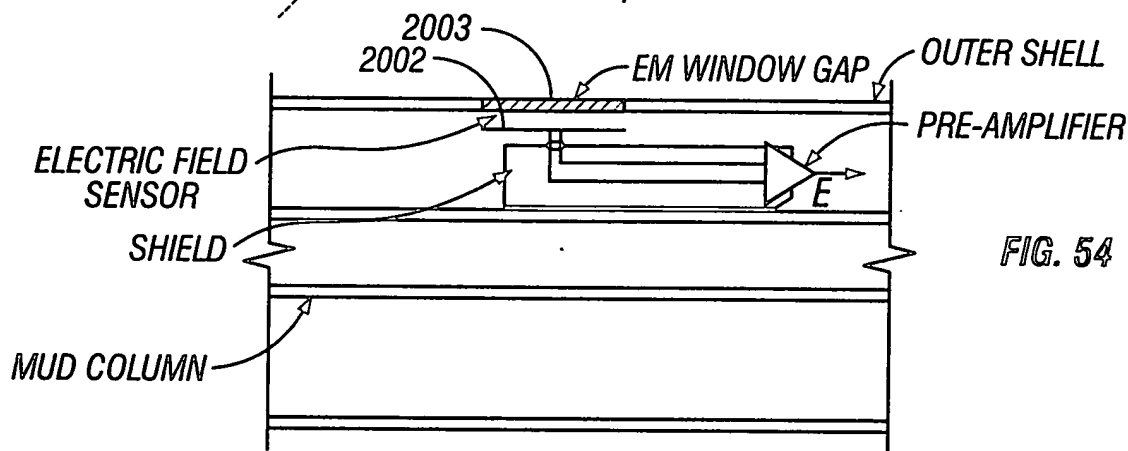


FIG. 54

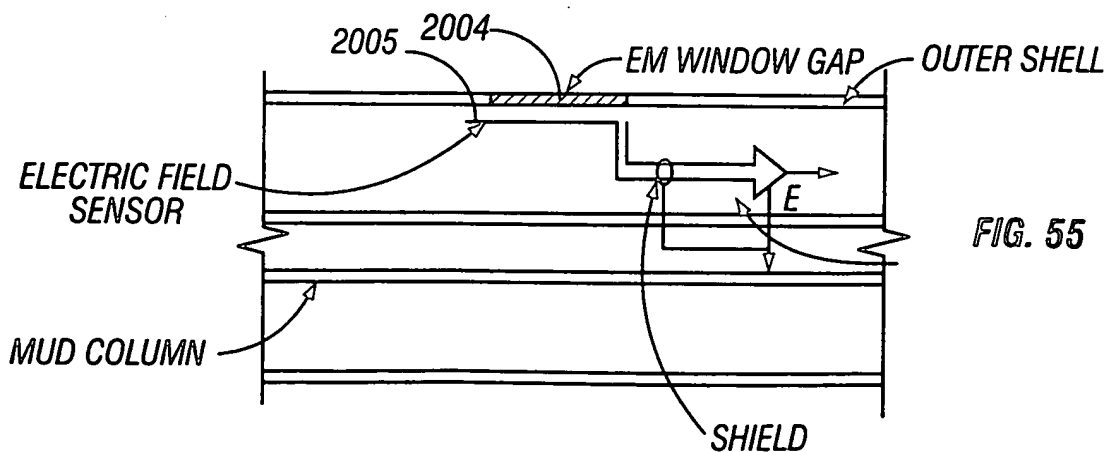


FIG. 55

INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
SERIAL NO.: 10/214,436
ATTORNEY: G. MICHAEL ROEBUCK
FILING DATE: AUGUST 7, 2002
DOCKET NO.: 414-15493-CIP
TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

22/41

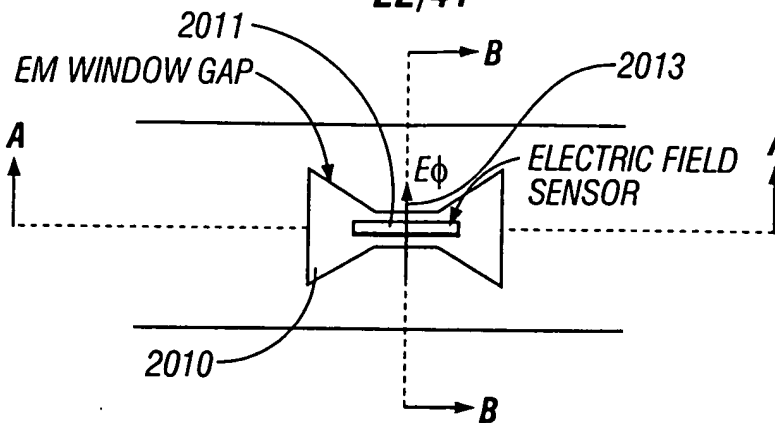


FIG. 56

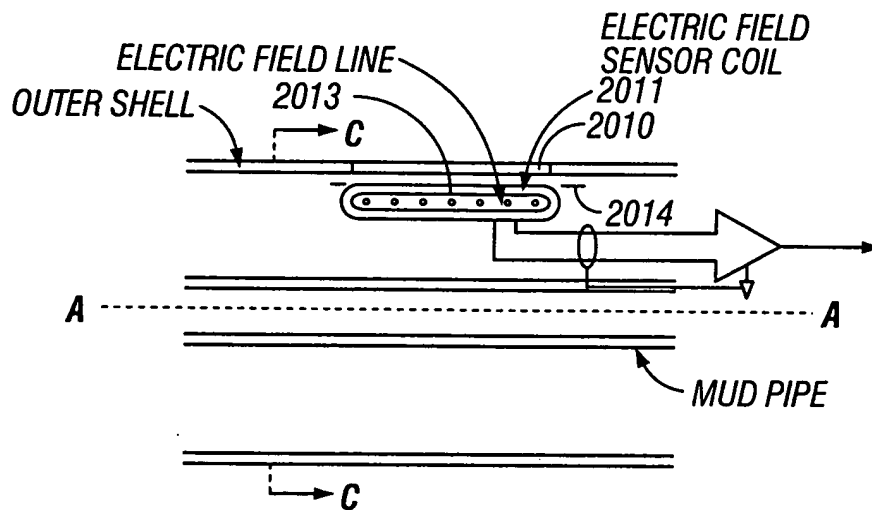


FIG. 57

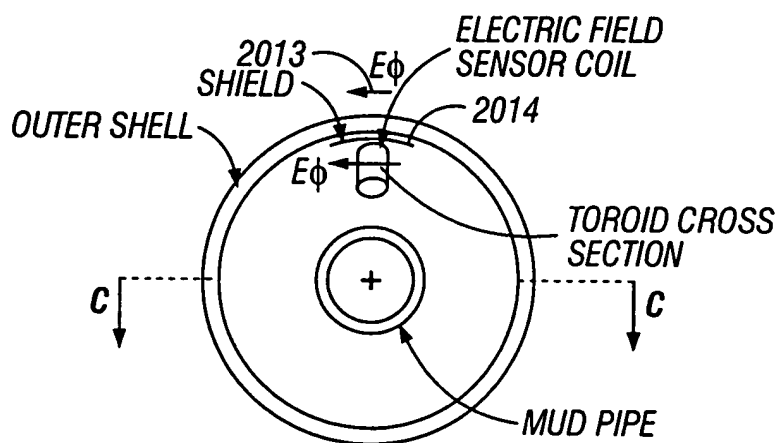


FIG. 58

23/41

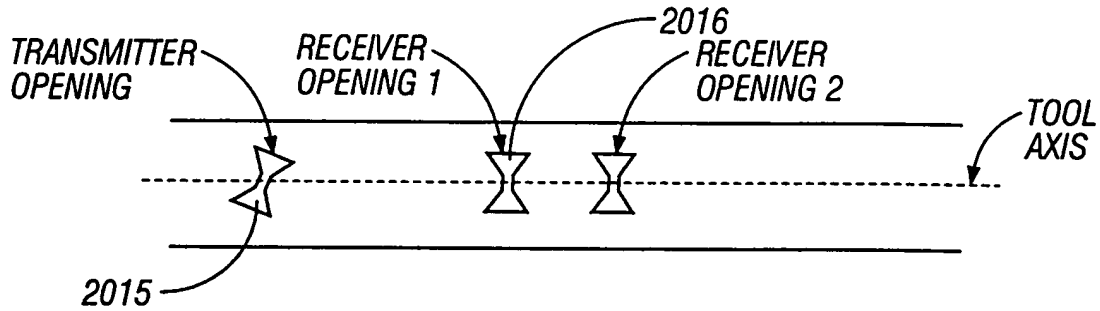


FIG. 59

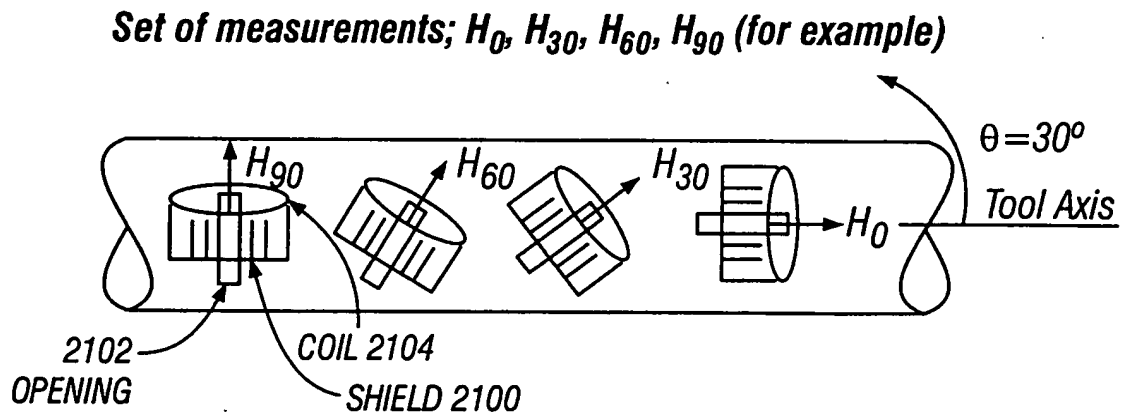


FIG. 60

24/41

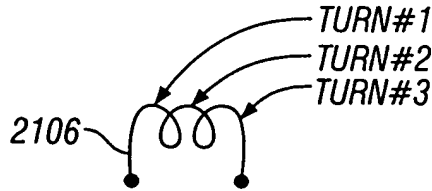


FIG. 61

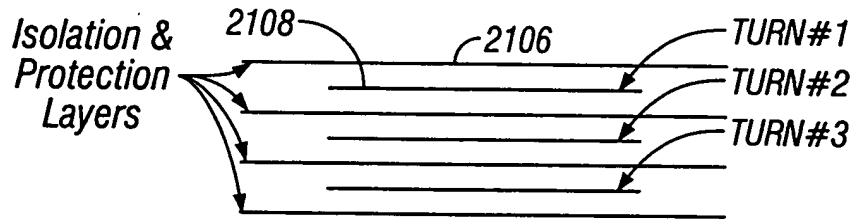


FIG. 62

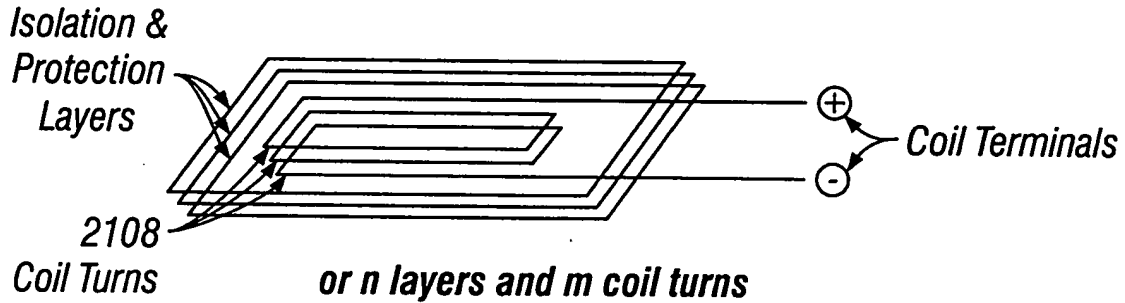


FIG. 63

2) At least one of the layers is a magnetic layer

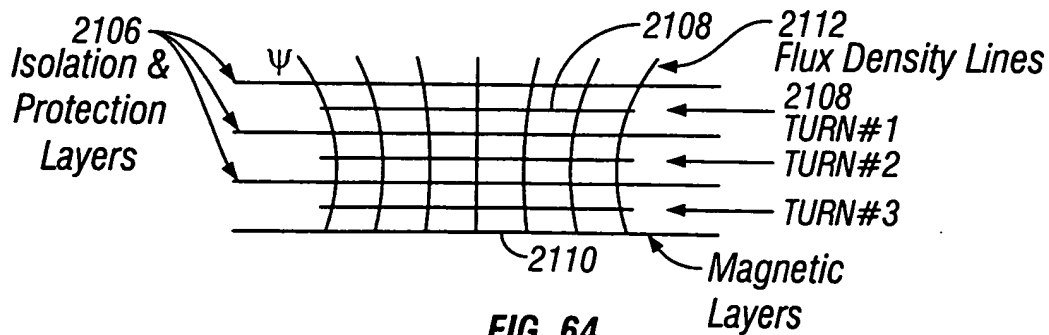


FIG. 64

25/41

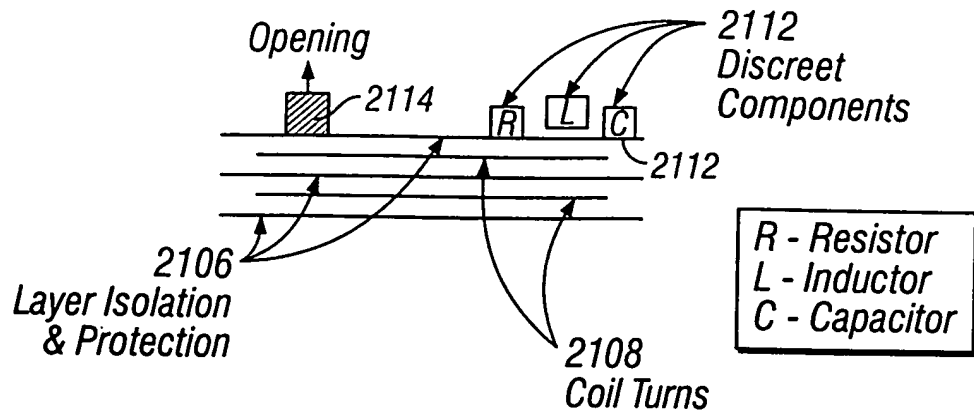


FIG. 65

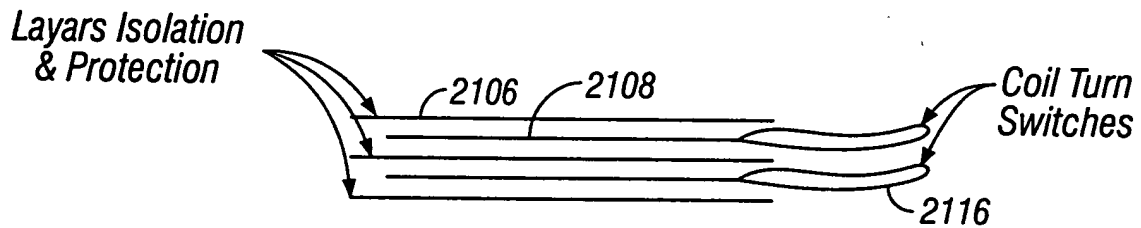


FIG. 66

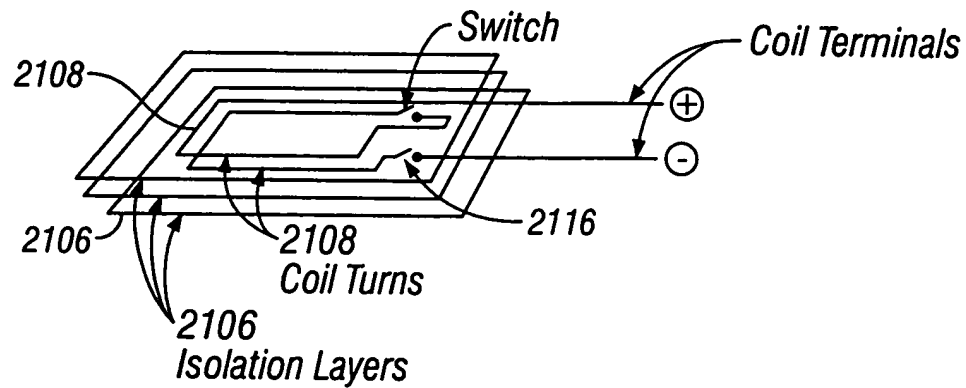


FIG. 67

26/41

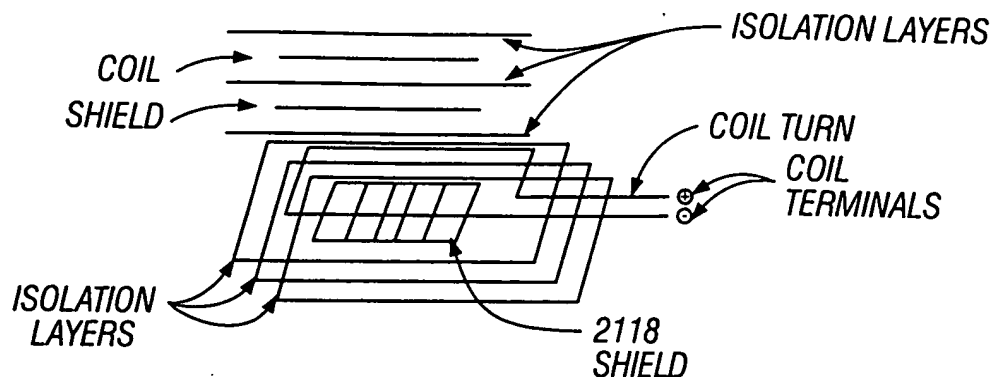


FIG. 68

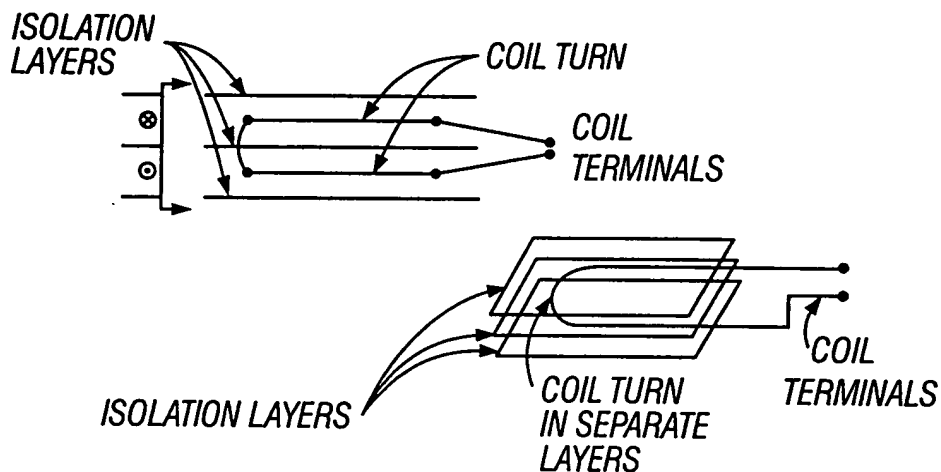


FIG. 69

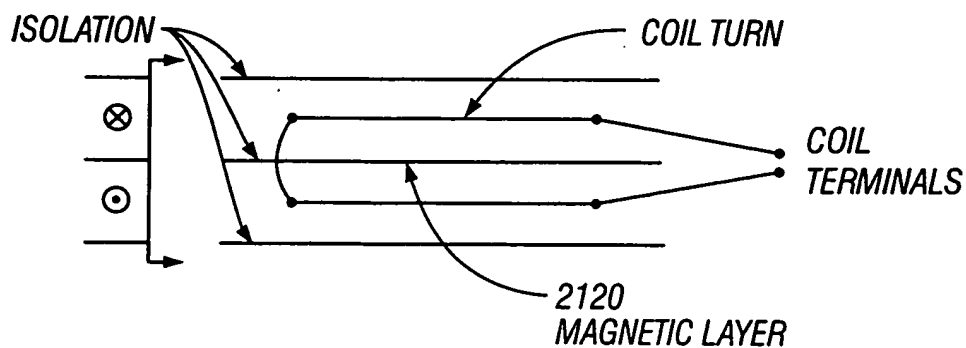


FIG. 70

27/41

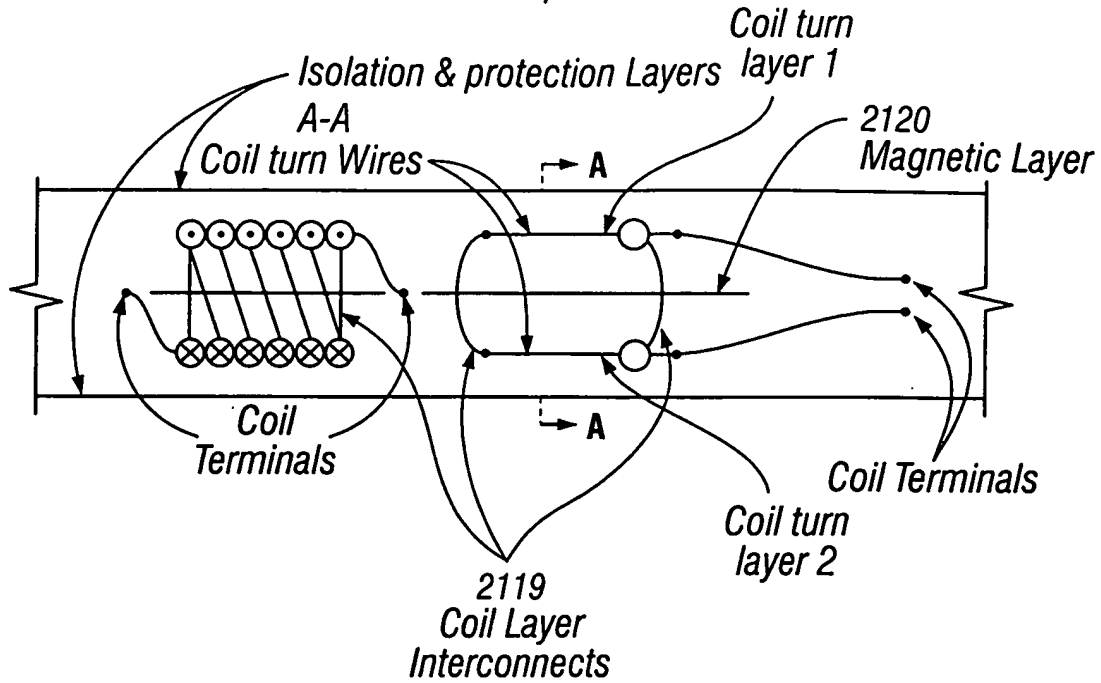


FIG. 71

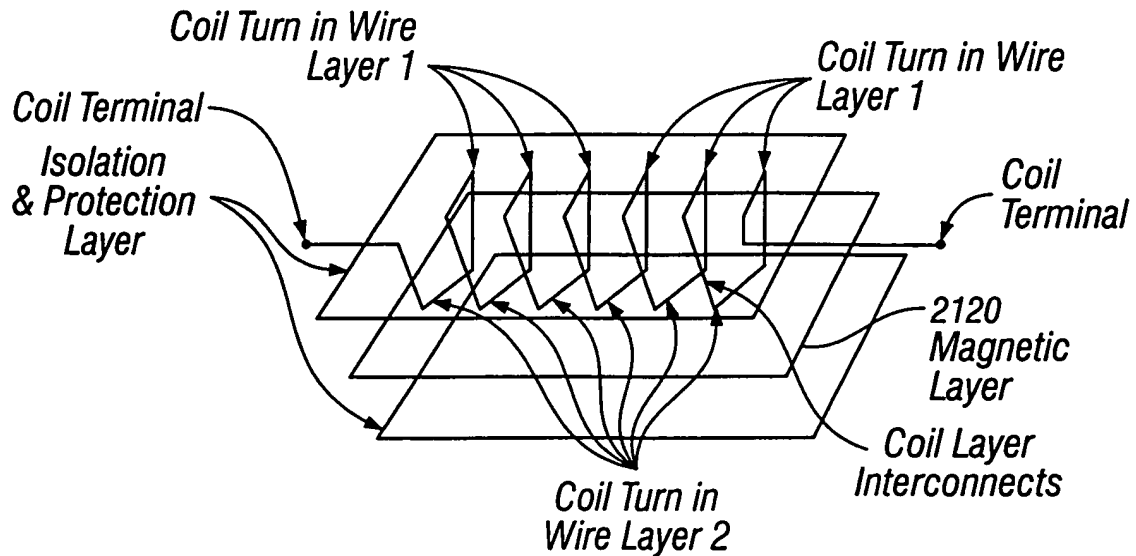


FIG. 72

28/41

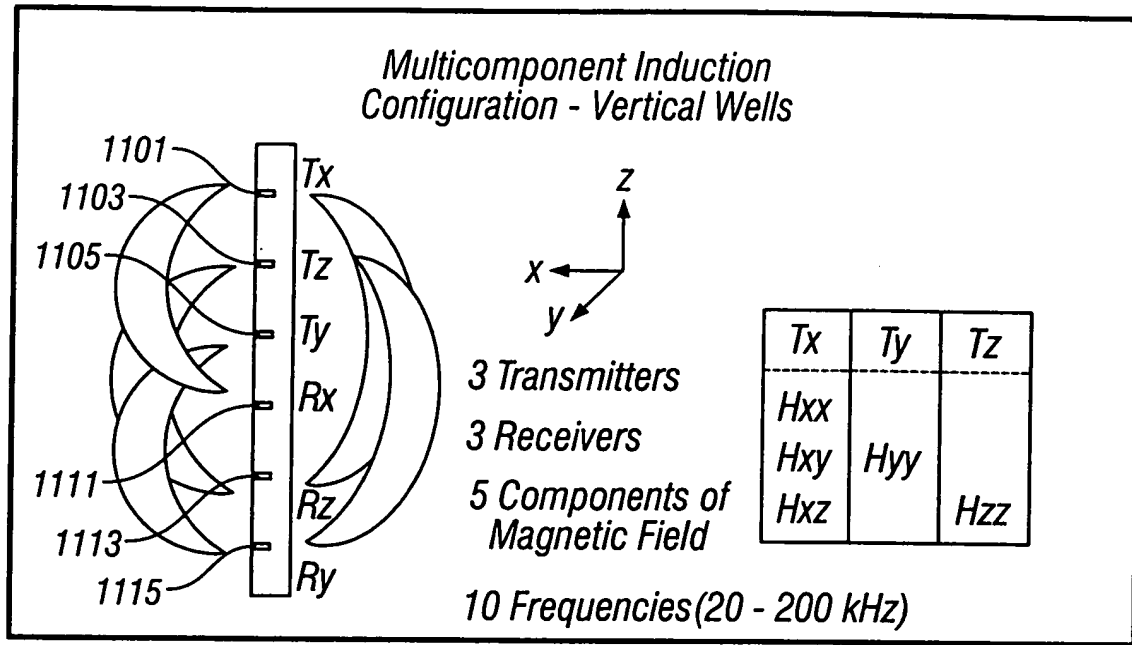


FIG. 73

Case 1:	Case 2:
1211 $R_h = 1 \text{ Ohm-m}, R_v = 1 \text{ Ohm-m}$	$R_h = 2 \text{ Ohm-m}, R_v = 2 \text{ Ohm-m}$ 1221
1213 $R_h = 4 \text{ Ohm-m}, R_v = 10 \text{ Ohm-m}$	$R_h = 4 \text{ Ohm-m}, R_v = 10 \text{ Ohm-m}$ 1223
1215 $R_h = 2 \text{ Ohm-m}, R_v = 2 \text{ Ohm-m}$	$R_h = 1 \text{ Ohm-m}, R_v = 1 \text{ Ohm-m}$ 1225

1m

FIG. 74

INVENTOR:
TITLE:

FANINI ET AL. FILING DATE: AUGUST 7, 2002
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS

SERIAL NO.:
ATTORNEY:

10/214,436 DOCKET NO.: 414-15493-CIP
G. MICHAEL ROEBUCK TELEPHONE NO.: 713-266-1130

REPLACEMENT DRAWINGS

29/41

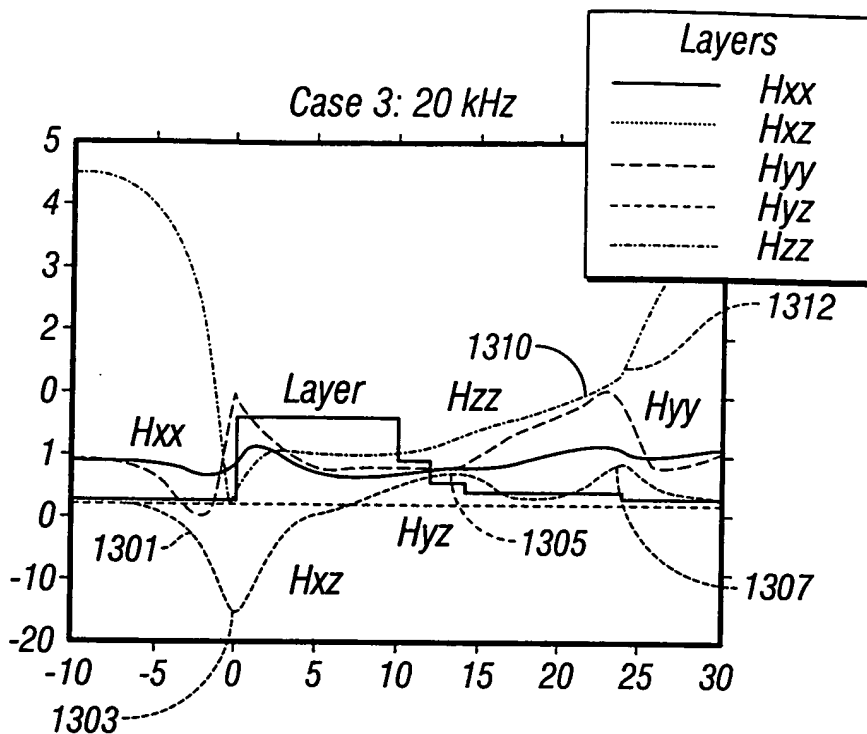


FIG. 75

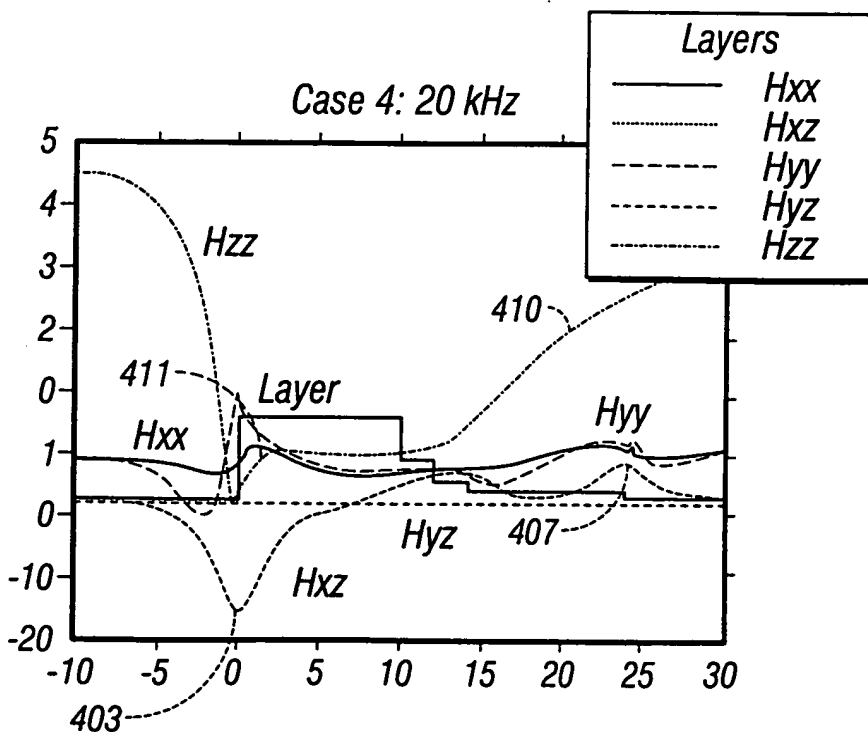


FIG. 76

INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
10/214,436
G. MICHAEL ROEBUCK
FILING DATE: AUGUST 7, 2002
DOCKET NO.: 414-15493-CIP
TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

30/41

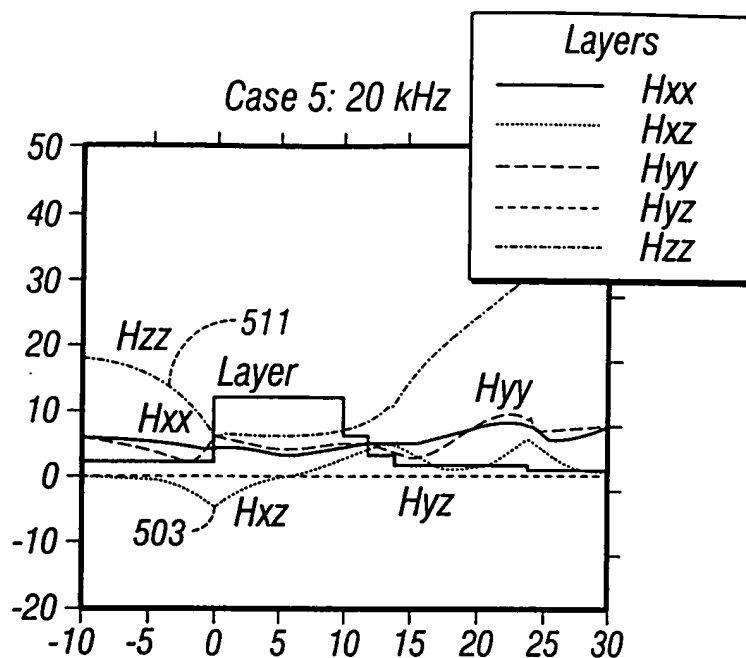


FIG. 77

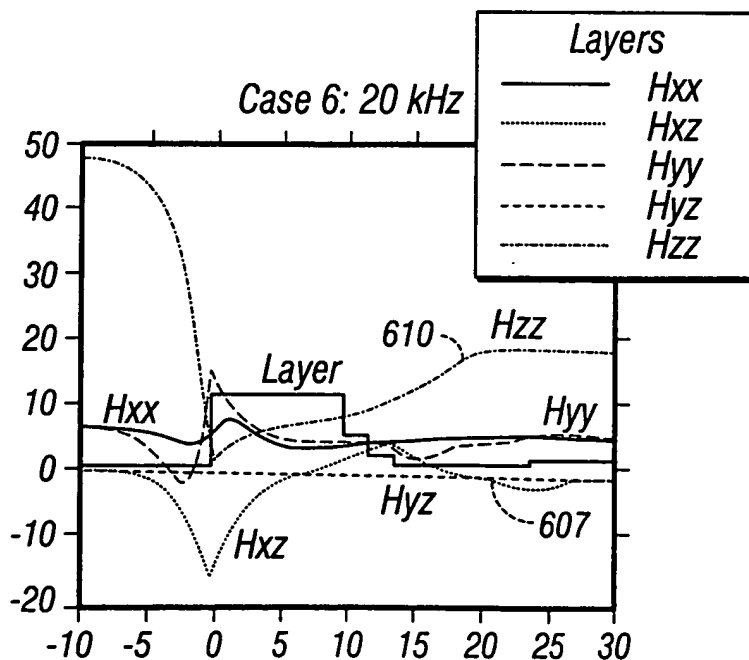


FIG. 78

INVENTOR:
TITLE:

FANINI ET AL.
METRIC AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
SERIAL NO.: 10/214,436
ATTORNEY: G. MICHAEL ROEBUCK
FILING DATE: AUGUST 7, 2002
DOCKET NO.: 414-15493-CIP
TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

31/41

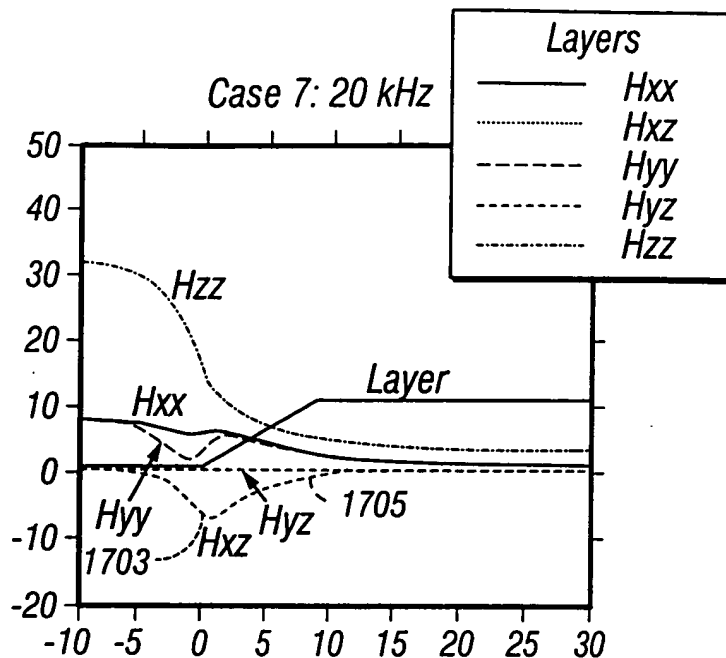


FIG. 79

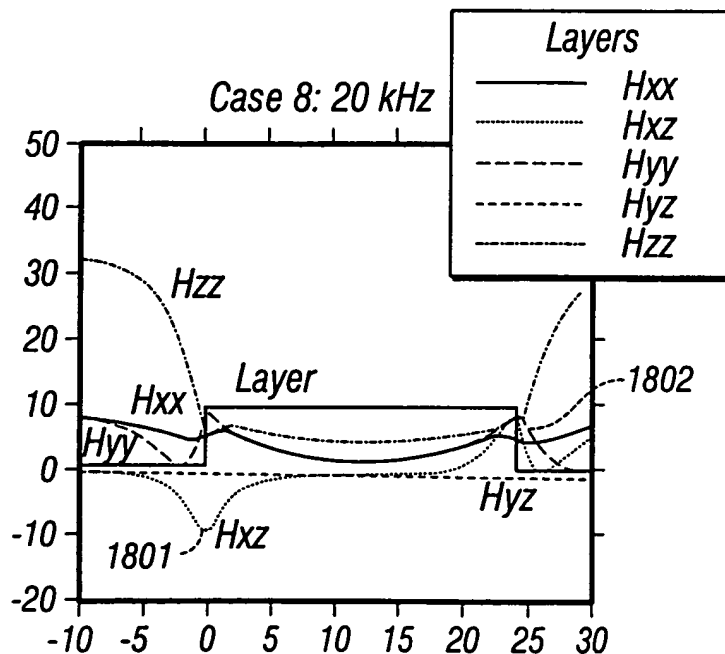
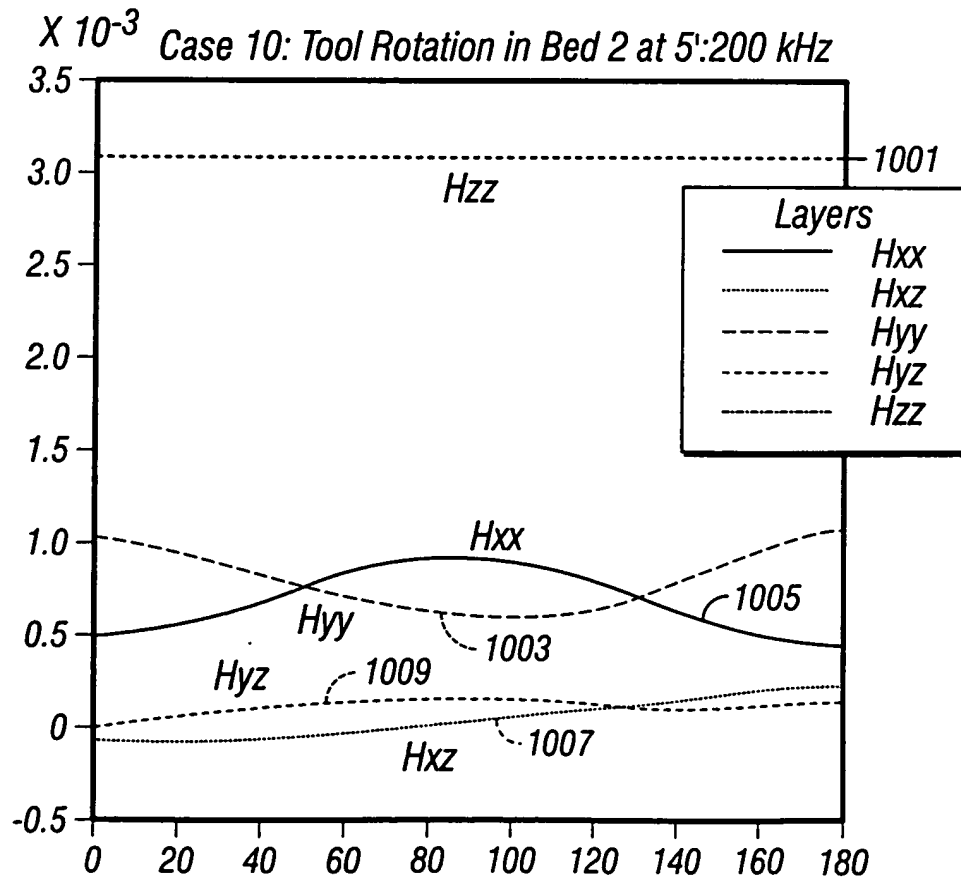
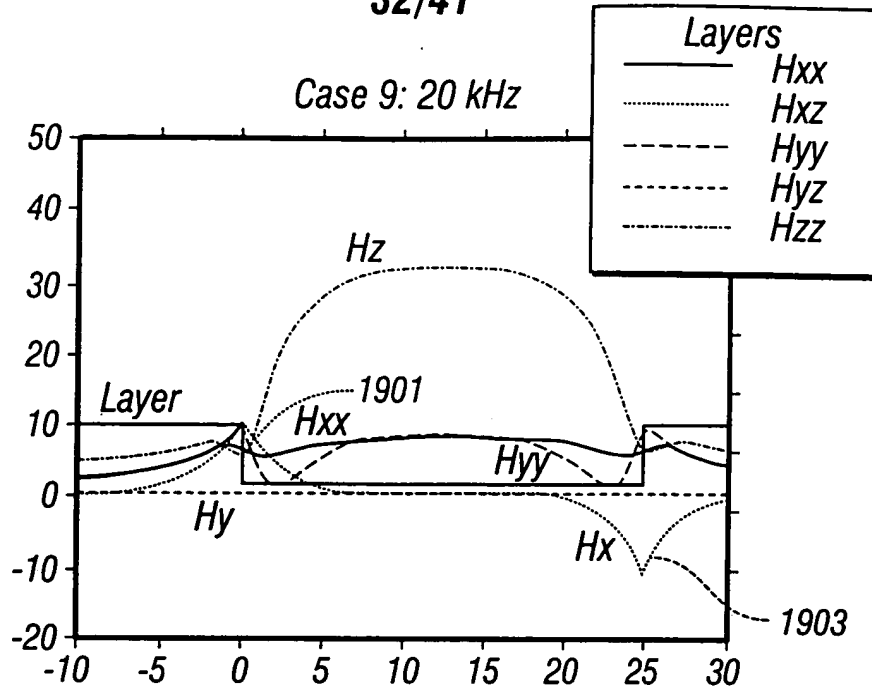


FIG. 80

32/41



33/41

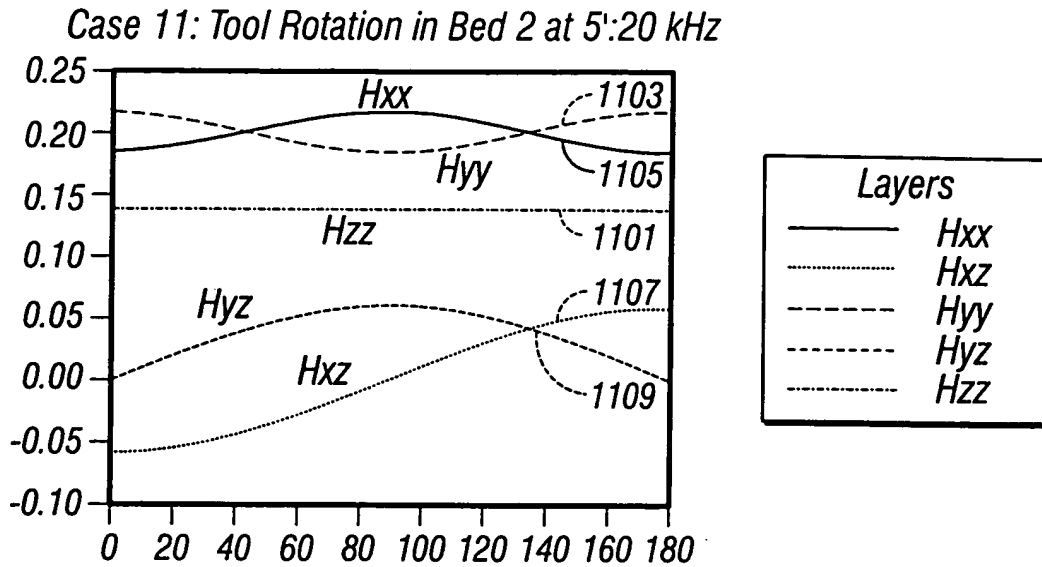


FIG. 83

Multicomponent Induction Configuration - Vertical wells

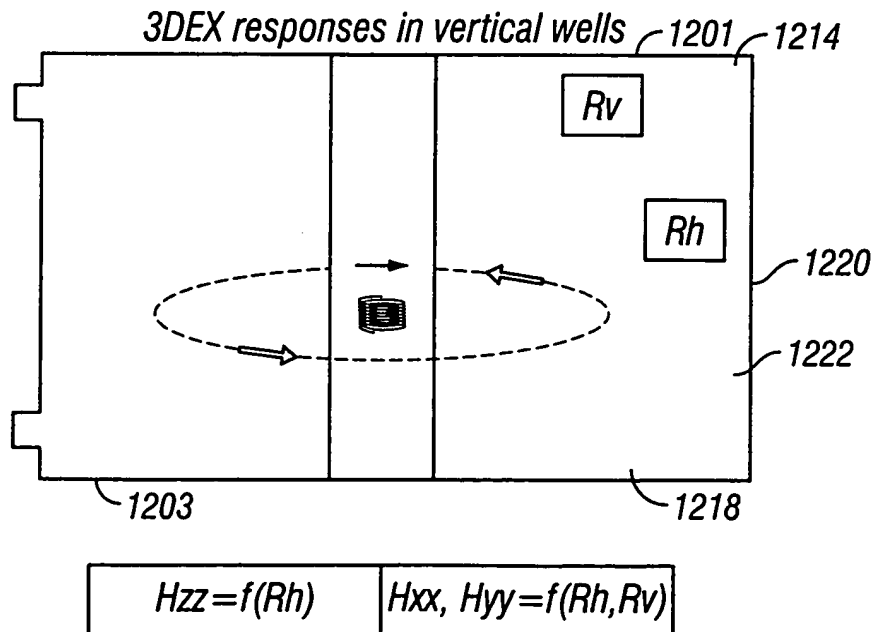


FIG. 84

INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
SERIAL NO.: 10/214,436 DOCKET NO.: 414-15493-CIP
ATTORNEY: G. MICHAEL ROEBUCK TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

34/41

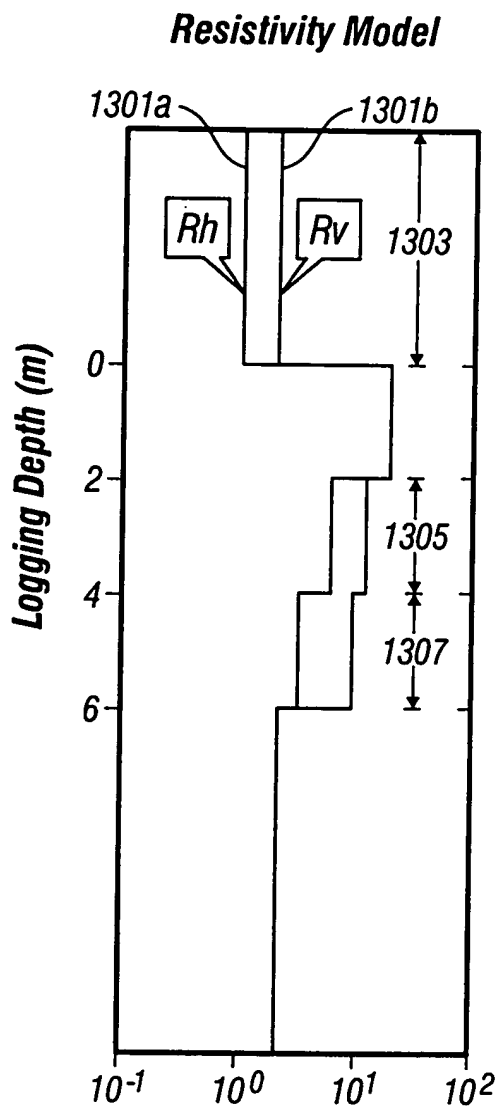


FIG. 85A

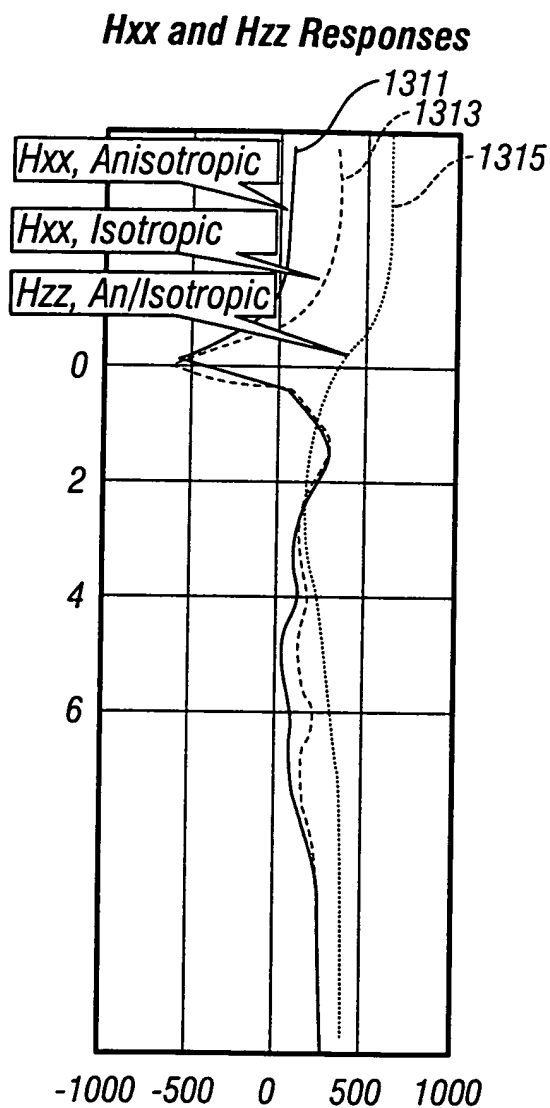


FIG. 85B

INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
10/214,436 DOCKET NO.: 414-15493-CIP
G. MICHAEL ROEBUCK TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

35/41

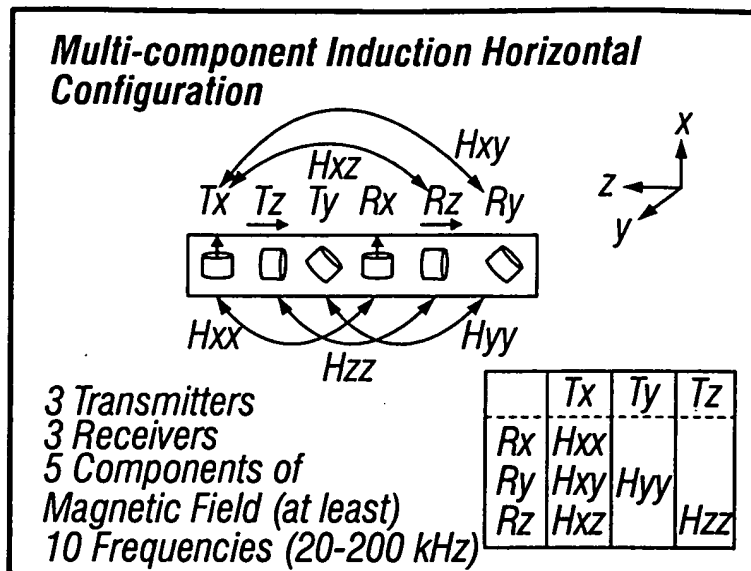


FIG. 86

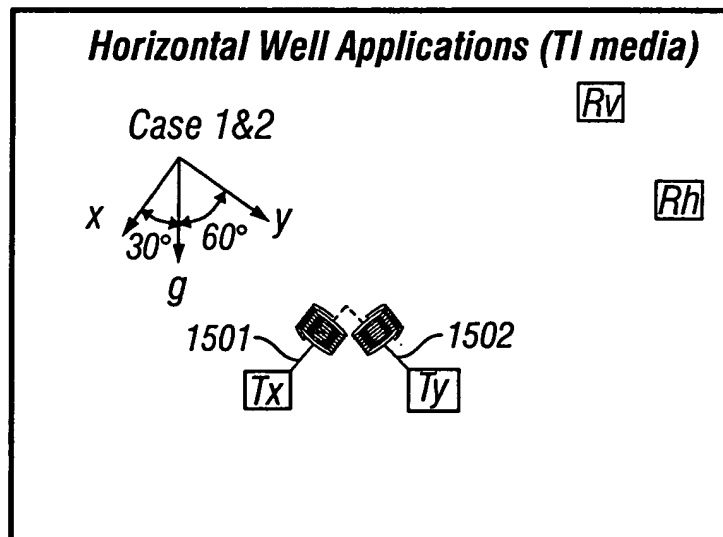


FIG. 87

INVENTOR:
TITLE:

FANINI ET AL.
METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY TA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
SERIAL NO.: 10/214,436 DOCKET NO.: 414-15493-CIP
ATTORNEY: G. MICHAEL ROEBUCK TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

36/41

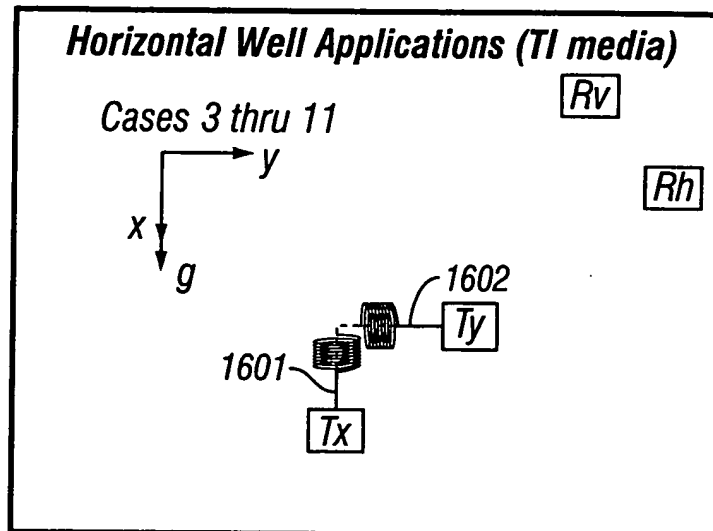


FIG. 88

37/41

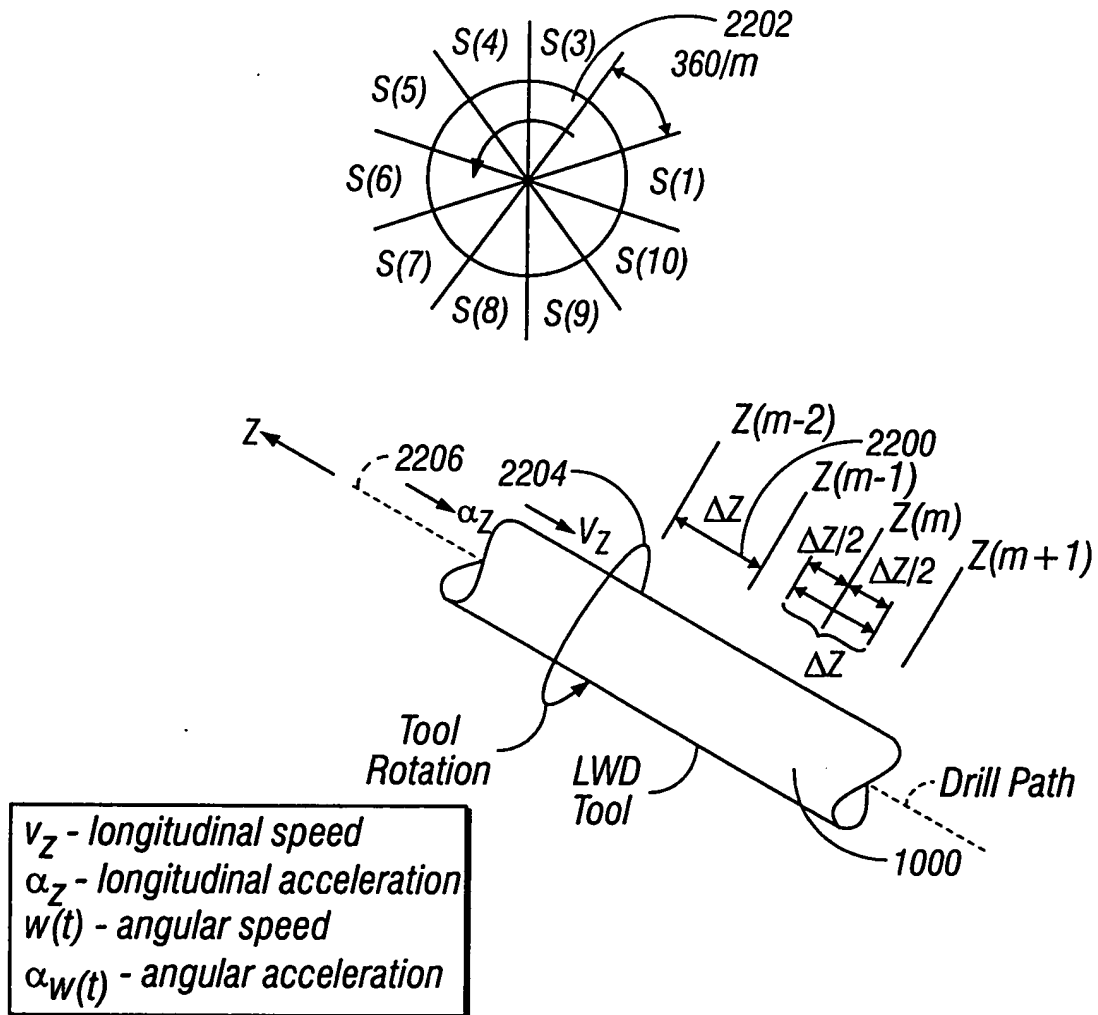


FIG. 89

INVENTOR:
TITLE:

FANINI ET AL. FILING DATE: AUGUST 7, 2002
METHOD AND APPARATUS FOR A MULTI-COMPONENT IN-FORMATION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS
10/214,436 DOCKET NO.: 414-15493-CIP
G. MICHAEL ROEBUCK TELEPHONE NO.: 713-266-1130
REPLACEMENT DRAWINGS

38/41

1) DATA AVERAGING ORGANIZATION
2D & Time Dependent CLUSTERED by Depth Interval & Azimuthal Sector

	S(1)	S(2)	S(3)	...	S(9)	S(10)
° °	° °	° °	° °		° °	° °
Z(m-1)	M(m-1,1)	M(m-1,2)	M(m-1,3)	°	M(m-1,9)	M(m-1,10)
Z(m)	M(m,1)	M(m,2)	M(m,3)	°	M(m,9)	M(m,10)
Z(m+1)	M(m+1,1)	M(m+1,2)	M(m+1,3)	°	M(m+1,9)	M(m+1,10)
° °	° °	° °	° °		° °	° °

M(m,R)
m → Depth Interval Index
R → Azimuthal Sector Number

FIG. 90

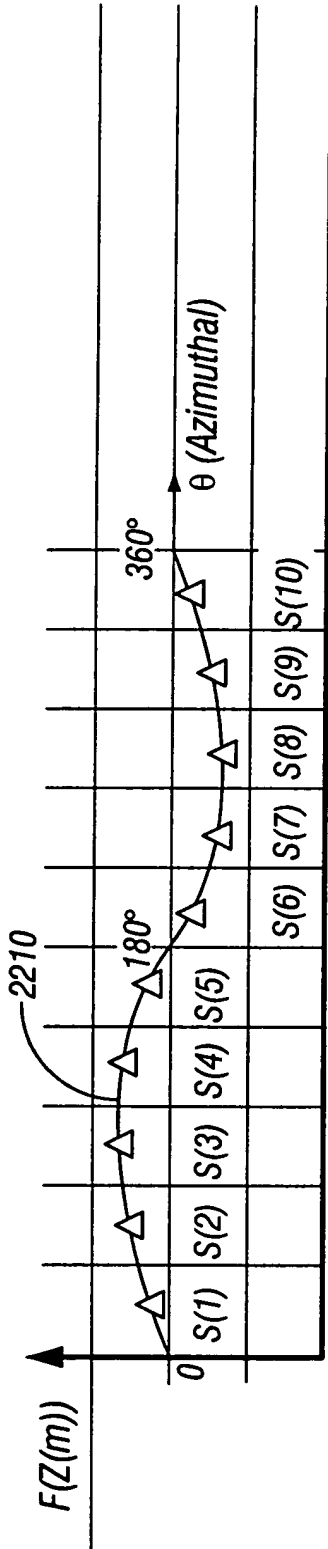


FIG. 91

II. TIME AVERAGING:

$M(m,R) = \text{AVERAGE}[\overline{f}(RD_{(m_2,r_2,t)})]$

RD-Raw Data at Depth Interval m, Sector R
And Time T_i

$T\mu(m,R) = \frac{T_{RD}(m,R)}{\sqrt{N}}$

FIG. 93

INVENTOR:
TITLE:

FANINI ET AL.

FILING DATE: AUGUST 7, 2002

METHOD AND APPARATUS FOR A MULTI-COMPONENT INDUCTION INSTRUMENT MEASURING
SYSTEM FOR GEOSTEERING AND FORMATION RESISTIVITY DATA INTERPRETATION IN
HORIZONTAL, VERTICAL AND DEVIATED WELLS

SERIAL NO.:
ATTORNEY:

10/214,436

G. MICHAEL ROEBUCK

DOCKET NO.: 414-15493-CIP

TELEPHONE NO.: 713-266-1130

REPLACEMENT DRAWINGS

40/41

Periodicity:

$H_{zz} \Rightarrow$ not sensitive to tool rotation.

H_{xx} & $H_{yy} \Rightarrow$ two cycles per tool complete rotation.

H_{yz} & $H_{xz} \Rightarrow$ one cycle per tool complete rotation.

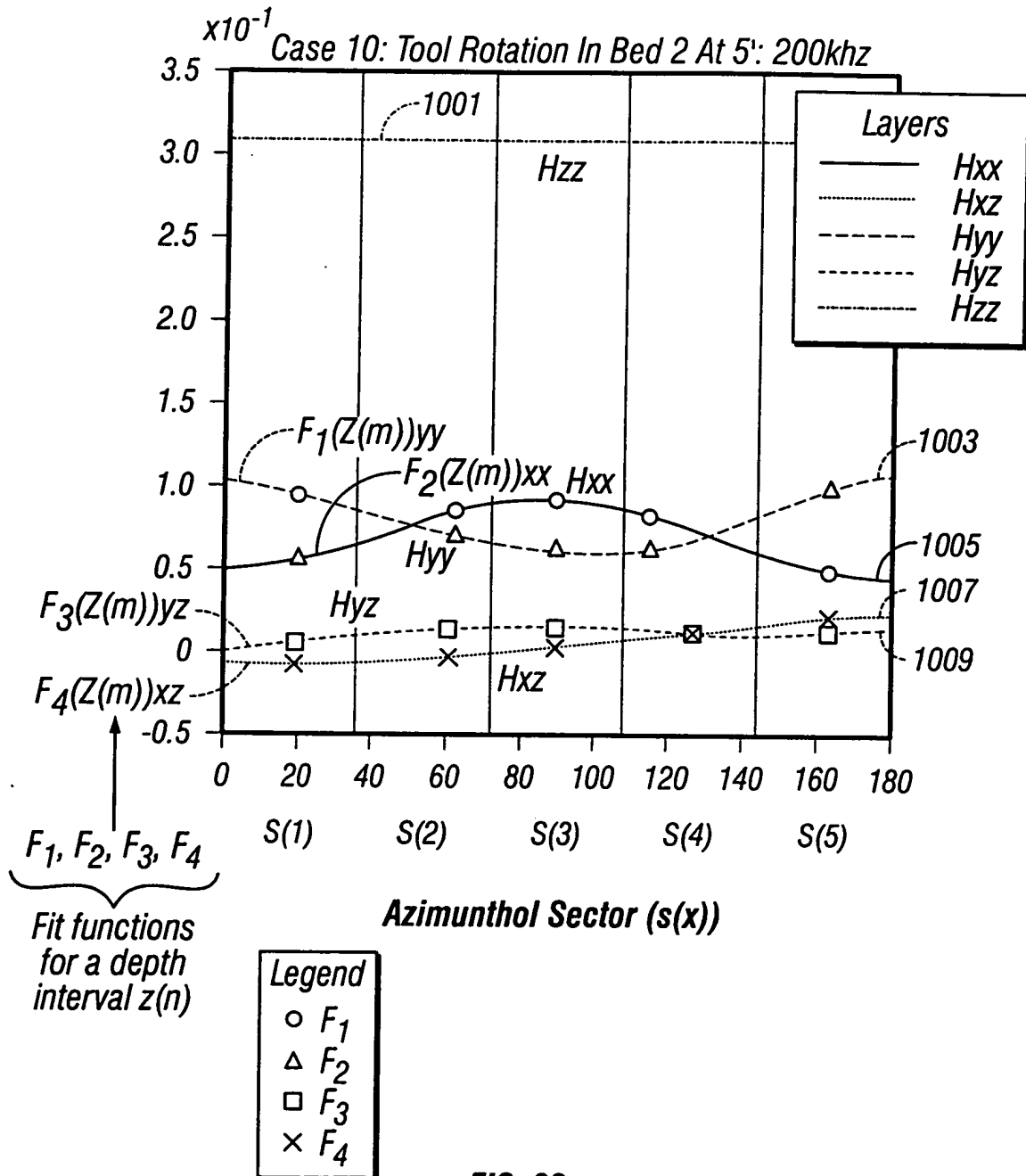


FIG. 92

41/41

